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ON THE SIGNIFICANCE OF THE FLEXOR POSTURE OF THE UPPER LIMB IN HEMIPLEGIA, WITH AN ACCOUNT OF A QUADRUPEDAL EXTENSOR REFLEX.

BY W. RUSSELL BRAIN.

(*From the Medical Unit, the London Hospital, and the Hospital for Epilepsy and Paralysis, Maida Vale.*)

INTRODUCTION.

IT is at first sight somewhat remarkable that so familiar a phenomenon as the flexor posture of the upper limb in hemiplegia should have received no satisfactory explanation, while the extensor posture of the lower limb which results from the same lesion has been thoroughly investigated and is comparatively well understood. The reason for this difference probably is that the latter attitude is paralleled in the extensor posture of the limbs which usually follows decerebration in all animals used in laboratory experiments. Flexor postures of the fore-limb, on the other hand, are comparatively rare sequels of experimental lesions of the nervous system. Further, while the lower limbs in man have retained their primitive locomotor function, the upper extremities have in the course of evolution acquired novel activities. It would therefore be surprising if much could be learned concerning the human upper limb from the results of experimental nervous lesions in animals lower in the evolutionary scale than primates. In the introduction to this paper we shall review the experimental conditions in which flexor postures of the fore-limb have been described in animals and the explanations which have been offered of the posture of the upper limb in hemiplegia in man.

Sir Charles Sherrington, in a personal communication, says: "In monkeys under certain grades of anæsthesia, and prior to 'deep'

anæsthesia, a flexed posture is frequently assumed, and for long periods, by the fore-limbs. Such 'anæsthesia' flexor postures of long and steady duration form an excellent background against which the inhibitory power of 'extensor' motor points in the 'motor' cortex can be revealed by stimulation of them. I do not remember ever to have seen in dogs any 'contracture' either flexor or extensor occurring in either fore-limb or hind-limb after extirpation of the cortex, 'motor' region or other. Nor do I remember having met with any description of it in dog or cat, either by Goltz or Munk, or Hitzig or Bickel. In these 'lower' mammals I certainly think it does not occur at all, or not to a perceptible degree." Such "anæsthesia" flexor posture of the fore-limb in the monkey is figured in myograph records by Graham Brown and Sherrington [3]. In the course of experiments on monkeys Graham Brown [2] observed that blanching and inexcitability of the motor cortex were associated with a flexor posture of the contralateral fore-limb. This observer also noted that in monkeys following decerebration anterior to the anterior colliculi, the hind-limbs tended to demonstrate extensor rigidity more frequently than the fore-limbs. While investigating the flexor posture of the fore-limb in the monkey, Graham Brown found that electrical stimulation of a spot in the cross section of the mid-brain dorsal to the cortico-spinal tracts and in the neighbourhood of the red nucleus and the posterior longitudinal bundle evoked a posture of the body of which flexion of the ipsilateral fore-limb formed a part. Associated with flexion of the ipsilateral fore-limb were extension of the opposite fore-limb and ipsilateral hind-limb and flexion of the opposite hind-limb. The head was twisted so that the back was directed to the stimulated side and the face to the opposite side, the neck was concave to the same side and the tail bent to the ipsilateral side also. Although this body posture includes as one of its constituents flexion of one fore-limb, in other respects it differs from both the "anæsthesia" posture and the posture which results from either unilateral or bilateral lesions of the pyramidal tract in man. As will be shown later, it is unlikely that it has the same meaning as the flexor posture of the fore-limb which Graham Brown observed to be associated with blanching and inexcitability of the opposite motor cortex.

Flexion of both fore-limbs may occur in decerebrate dogs, cats and other animals under certain conditions. Magnus [6] has shown that in dogs and cats after decerebration extension of the neck leads to an increase in the extensor tonus of the fore-limbs, while flexion of the

neck diminishes it. The meaning of these changes is made clear by observations of the behaviour of an intact animal. When a cat, for example, looks up at a piece of meat held in the air, the fore-limbs are extended; when it eats from a plate they become flexed. Extension and flexion of the neck in these circumstances evoke appropriate modifications in the posture of the limbs.

Davis and Pollock [4] have recently shown that in cats that have been "decerebrated" by ligature of the carotids and basilar artery, without direct injury to the brain, the usual extended posture of the fore-limbs in the decerebrate animal becomes changed to one of flexion following extirpation of both labyrinths. These authors consider this to be due to the drooping of the head with flexion of the neck which follows bilateral labyrinthectomy. It would appear, therefore, to be simply a manifestation of the neck reflex just described. Magnus [6] and Davis and Pollock [4] have noted that picrotoxin poisoning converts the extensor spasticity of all four limbs in decerebrate animals into a flexor spasticity. Magnus regards this as the result of a disturbance of reciprocal innervation induced by the drug, which causes flexion to be evoked by postural reflexes which usually produce extension. Davis and Pollock, on the other hand, regard the change as due to the depressant effect of picrotoxin on the labyrinth, and the resulting flexor posture as the same as that which they have shown to follow bilateral labyrinthectomy in decerebrate animals.

Bazett and Penfield [1] have observed rigid semiflexion of the fore-limbs in some of their chronic decerebrate preparations in cats, but they do not state whether this posture was related to flexion of the neck. It is possible that the flexor posture these authors have described, like that observed by Magnus and Davis and Pollock, was caused by flexion of the neck or by depression of labyrinthine function. As will be seen, the evidence indicates that the significance of the flexor posture of the upper limb which occurs in hemiplegia in man and in certain experimental circumstances in monkeys is entirely different from that of the flexor posture of the fore-limbs which may be obtained in decerebrate animals under the conditions just described.

So far as I am aware, no explanation of the occurrence of the flexor posture of the fore-limb in the monkey has been offered. Some suggestions have been made as to the meaning of the same posture when it occurs in man as a result of a lesion of the pyramidal tract, but none so far put forward is entirely satisfactory. Walshe [13] regards it as "traceable to the altered functions the upper limb exercises in

man and to its complete lack of locomoter function." In man, "if it can be said to possess a primary inherent function, it is that of embrace, grasping, and of carrying food to the mouth." Riddoch and Buzzard [8] adopt a somewhat similar view. They believe that "the grasping and conveyance of food to the mouth is probably the elementary function of the human hand and arm." After describing the posture of the upper limb in man during fast running, these authors continue: "The flexed attitude of the upper limb in relation with the extended lower limb in hemiplegia might be held to have a locomotory significance. This, in fact, may be true, and certainly many hemiplegic patients when walking automatically swing their paralysed arms as they move forward their unaffected limbs. But taking into consideration the fact that the hemiplegic patient, as a rule, recovers the power of voluntary flexion better than that of extension of his upper limb, the rigidity of the flexors is probably more intimately connected with the prehensile function of the limb."

To the conclusions of Walshe and Riddoch and Buzzard there are two objections which seem to render them untenable. The muscles employed by man in the conveyance of an object to the mouth are not entirely the same as those which exhibit hypertonia in hemiplegia. In the hemiplegic we find the upper limb in a position of adduction and internal rotation at the shoulder, flexion at the elbow, pronation of the fore-arm and flexion of the wrist and fingers. In conveying an object to the mouth, however, abduction and flexion of the shoulder play an important part. It is necessary only to raise the hand to the mouth while keeping the arm adducted to realize how unnatural and clumsy such a movement is. In this respect man differs from the apes and monkeys, for in these animals the great length of the forearm relatively to the upper arm enables the animal to bring objects to the mouth without a movement at the shoulder. So long is the fore-arm in some species of monkey that the animal can scratch its scalp while keeping the upper-arm close to its side.

A further and more serious objection to the view that the posture of the upper limb in hemiplegia is related to prehension is based on more general considerations. Prehension in man depends upon the integrity of the pyramidal tracts. It does not occur in the infant before these tracts become myelinated, and is impossible if they become completely destroyed. It is well recognized that the function "released" by a lesion of the nervous system is of a more primitive character than the function lost. It would be contrary to this universal experience if

a lesion of the tract serving the function of prehension should "release" a posture which was the embodiment of the very activity destroyed. Indeed, as Walshe says, the poor recovery of function in the upper limb in hemiplegia, as compared with the lower, is due to the fact that "the upper limb is more dependent on cortical control and innervation than the lower limb which is still engaged in its primitive motor function." For this very reason, then, it is unlikely that the flexor posture of the upper limb in hemiplegia is related to its biologically novel functions of "embrace, grasping, and of carrying food to the mouth."

Wilson [15] regards the flexor posture of the upper limb in hemiplegia as an incomplete form of the "decerebrate" posture. "The upper extremity . . . " he says, "assumes an attitude in flexion at the elbow, commonly, and not extension; nevertheless, the adduction at the shoulder, pronation of the fore-arm and flexion of the wrist and fingers, are to be ascribed to the development, incomplete though it may be, of the decerebrate posture." It is, however, doubtful whether it is justifiable to assume that the posture of a limb can be regarded thus as merely a sum of its parts, so that one posture can be looked upon as an "incomplete" form of another posture, which it resembles in some particulars. Sherrington [10] says concerning the decerebrate preparation: "The distribution of the tonus in the limb musculature reveals, therefore, arrangement on a plan of strict co-ordination. . . . Thus this reflex tonicity which, when seen in a single isolated muscle prepared for the myograph, does not carry on the face of it any very obvious biological purpose, does carry a clear and unmistakable biological purpose when the phenomenon is followed in the musculature as a whole." The difference between flexion and extension at the elbow in the posture of the upper limb appears so fundamental that it is much more probable that the flexed and extended postures are separate co-ordinated wholes, each possessing its own biological purpose, than that the former is merely an "incomplete" form of the latter.

Minkowski [7] regards the posture in hemiplegia as a reversion to a fœtal attitude. He has investigated tonus, movements and reflexes in a number of human fœtuses, aged from two to five months, immediately after their removal from the uterus by Cæsarian section. On the fœtal posture he writes as follows: "Lorsque le fœtus est couché dans une position horizontale, les bras sont habituellement en adduction, fléchis au coude à un angle un peu obtus, et les mains reposent sur la poitrine, l'une à côté ou au-dessus de l'autre; les mains et les doigts sont le plus souvent étendus, quelquefois légèrement fléchis dans les phalanges

distales; dans les extrémités inférieures il y a le plus souvent une flexion légère des hanches et des genoux, tandis que les orteils sont en extension." This posture, Minkowski considers, depends upon various factors, "l'élasticité des téguments, les tonus propre et spinal des muscles, les réflexes toniques de position d'origine vestibulaire, &c." He further states that "ce sont précisément les muscles déterminant souvent les contractures dans l'hémiplégie organique (biceps, grand pectoral, adducteurs de fémur) qui prennent le devant sur leurs antagonistes chez le fœtus." This, however, is only partly true, for, apart from adduction at the hip, the posture of the lower limb in hemiplegia is the opposite of the fœtal posture. In the former, it is extended, in the latter it is flexed at the hip and knee. Unless, then, we are again to lay more stress on a similarity in one detail than on a difference in the total plan, we cannot regard the posture of the lower limb in hemiplegia as a fœtal attitude. Nor can we so regard the posture of the hemiplegic upper limb, unless we are prepared to assume that it bears no relation to that of the lower, an assumption which, as will be seen, is erroneous.

The Flexor Posture of the Fore-limb in Anthropoid Apes and Monkeys and its Evolutionary Significance.

The normal resting posture of the fore-limbs in anthropoid apes and monkeys is one of flexion, and resembles the posture of the human upper limb in hemiplegia. The resting posture of the chimpanzees and orangs, and of all species of monkey that I have been able to observe in the Zoological Society's Gardens, is the same. The animal sits erect and unsupported by the fore-limbs. These are adducted and internally rotated at the shoulder, flexed at the elbow, pronated and flexed at the wrist, metacarpo-phalangeal and inter-phalangeal joints. The hands are usually superimposed, so that the palm of one is in contact with the dorsum of the other; sometimes the fore-arms overlap to some extent in the same way. The hind-limbs are flexed at the hip and knee. One foot is usually flat upon the ground, while the other, somewhat plantar-flexed and inverted, rests upon it. The weight is supported upon the buttocks and the sole of the foot. This attitude is illustrated in fig. 1, a photograph of an orang-utan with the left upper limb in the resting posture.

The significance of the simian resting posture is obscure until it is viewed in the light of observations made upon animals lower in

the evolutionary scale. There are few quadrupedal mammals which do not, from time to time, for brief intervals rear themselves upon their hind-limbs. Some, such as the kangaroo and jerboa, adopt this posture permanently. All species of animal which I have been able to observe in this attiude have exhibited a posture of the fore-limbs similar to the simian resting posture. This may be seen in animals as varied in their modes of life as the horse, dog, otter and squirrel. In the dog, for example, the fore-limbs are adducted and internally rotated at the

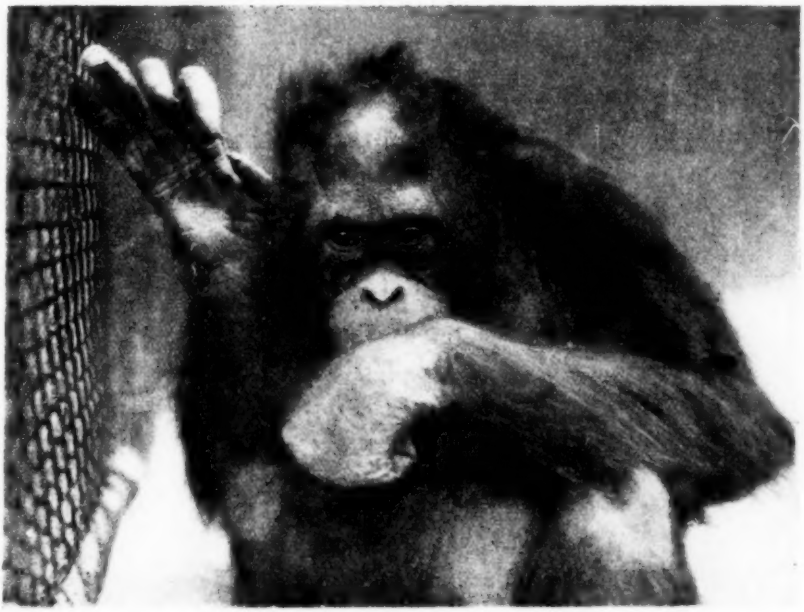

FIG. 1.—Orang-utan, with left fore-limb in the resting posture. (Photograph by Photopress.)

shoulder and flexed at the elbow and wrists. In most species below the primates, the erect posture is adopted only for brief periods and even then is somewhat unstable. In monkeys and apes, although locomotion on the ground is still almost entirely quadrupedal, the erect posture is habitually adopted during rest and the flexor posture of the fore-limbs has become the usual resting posture.

The primate resting posture would appear to be a most important stage in the evolution of the erect posture of man. Keith [5], on anatomical grounds, considers that man in the course of evolution from

a pronograde monkey has passed through three stages. In the first, the monkey has become a small orthograde ape of the type now represented by the gibbon. In the second stage, this small hylobatian ape has developed into an animal resembling the great anthropoids. The final phase was the evolution of man as a plantigrade variation of a great anthropoid ancestor. An essentially similar view is expressed by Elliot

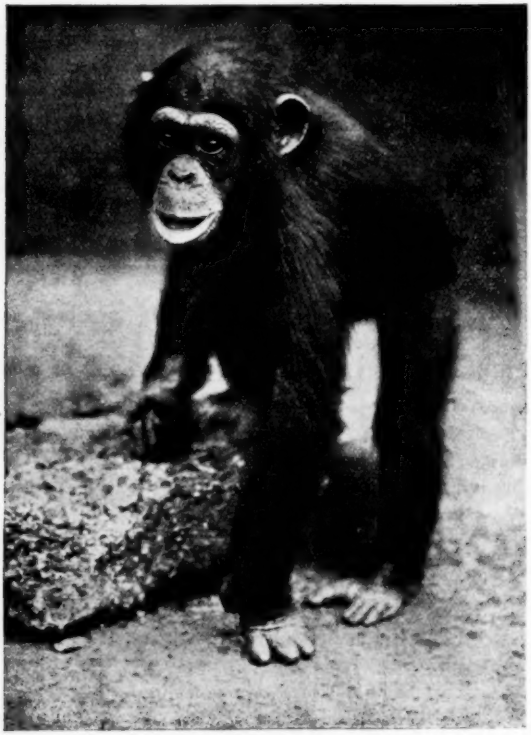

FIG. 2.—Chimpanzee in attitude of quadrupedal standing.
(Photograph by D. Seth-Smith, F.Z.S.)

Smith [11]. The erect resting posture was, however, inherent in the stock before these changes began. As Keith puts it, "the nerve centres of the spinal cord, mid-brain and hind-brain of a monkey are organized to carry out the reflexes necessary for a pronograde posture. It is habitual for monkeys of all kinds to assume a sitting or semi-erect posture when resting; to maintain this attitude, the nerve mechanisms

must have in them a nucleus which may have been expanded into that elaborate mechanism which serves the needs of orthograde apes." This postural mechanism is extremely ancient, since it is present in apparently all quadrupeds. In primates, however, it has become greatly stabilized. This is perhaps due to the fact that they have ancestrally adopted an arboreal life which necessitates progression in a plane vertical to the earth's surface. For in climbing a tree the posture naturally adopted is an erect one, and the first step in climbing is to assume that primitive erect posture which all quadrupeds adopt from time to time for brief intervals.

It will be necessary later to refer also to the posture of the fore-limb in the anthropoid during quadrupedal standing, and a brief description of this attitude may be given at this point. When an anthropoid ape stands on all-fours, the fore-limbs are extended at the elbow, the wrist is straight and the fingers are extended at the metacarpophalangeal and flexed at the interphalangeal joints. The animal thus rests the weight of the fore part of its body upon the dorsal surfaces of the middle phalanges which are in contact with the ground (fig. 2).

Factors reflexly influencing the Posture of the Upper Limb in Hemiplegia.

In this section it is proposed to consider the way in which the posture of the affected upper limb in hemiplegia is influenced by changes in the posture in other parts of the body, and by alterations in the position of the whole body in space. Observations have been made on a number of patients suffering from hemiplegia, and three representative cases are reported in the Appendix. When one considers the elaborate technique for isolating proprioceptor organs which Magnus and his fellow workers have found necessary to unravel the complexity of postural integration, it becomes clear that no similar direct analysis can be based upon clinical material. Facts already established by such methods in animals can, however, be used to illuminate clinical observations in man. Complementary to this physiological approach is the biological investigation which inquires the significance of a posture as an integrated whole. Both these methods are required for a satisfactory interpretation of posture.

(1) *The Quadrupedal Extensor Reflex.*

We have seen that the posture of the upper limb in hemiplegia resembles in detail the resting posture of the fore-limb which is found

in anthropoid apes and monkeys, and which is closely related to the assumption by these animals of an erect attitude during rest. These considerations led me to inquire what modifications of the flexor posture of the upper limb in hemiplegia would result from changes in the posture of the body as a whole, and especially what would occur if a hemiplegic patient were made to assume a quadrupedal attitude. This

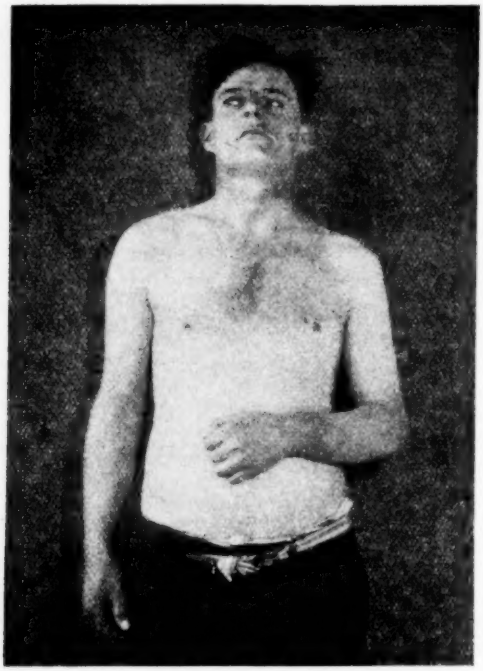

FIG. 3.—Patient (No. 1) suffering from left hemiplegia, showing posture of affected upper limb associated with erect attitude. Compare with fig. 1.

change of posture has been found to evoke a reflex extension of the affected upper limb, leading to an extensor posture which is maintained as long as the patient remains in the quadrupedal position. This reflex extension I have termed the quadrupedal extensor reflex in the upper limb in hemiplegia.

The flexor posture of the upper limb characteristic of the hemiplegic patient has already been described in detail. If such a patient while standing or kneeling is made to lean forward, the quadrupedal extensor

reflex can in many cases be elicited. When the patient is leaning to such an extent that the extensor muscles of the hips and spine are no longer able to support the weight of the trunk, the affected upper limb assumes a new posture. It becomes flexed at the shoulder and still more strongly adducted and internally rotated at this joint than previously. At the elbow, a posture of flexion gives place to one of extension. The pronation of the fore-arm becomes increased. The wrist and fingers remain flexed. If the patient is allowed to rest his weight partly upon the extended upper limb, the wrist may become somewhat extended,

FIG. 4.—Patient (No. 1) suffering from left hemiplegia, showing posture of left upper limb associated with quadrupedal attitude. Compare with fig. 2.

but the fingers remain flexed, the dorsal surfaces of the two distal phalanges being in contact with the surface upon which the upper part of the body is being supported (figs. 4, 5 and 6). This new extended posture is maintained by an extreme hypertonia of the muscles concerned, particularly of the extensors of the elbow. The limb may become so rigid in extension that it cannot passively be flexed. It is remarkable to observe the conversion of a limb which the patient could not voluntarily extend into a rigidly extended prop capable of supporting for a time the weight of the upper part of the body.

The quadrupedal extensor reflex appears to be elicitable in the great majority of patients with hemiplegia. In those in whom the loss of

power and flexor spasticity are slight, the substituted extensor spasticity is also slight, and it is difficult to exclude voluntary effort as responsible for the adoption of the extended posture. The more complete the loss of power and the greater the flexor spasticity, the better can the reflex be evoked and the more rigid in extension does the limb become. The usual cause of difficulty in eliciting it is the inability or the unwillingness of the patient to abandon the support of the extensor muscles of the hips and spine. To overcome this reluctance, it is helpful to have an assistant who partially supports the patient by placing an arm beneath his chest as he leans forward.

The quadrupedal extensor reflex is perhaps the most interesting and illuminating of the reflex modifications of the flexor posture of the upper limb in hemiplegia. Regarded physiologically, the change from flexion to extension may be said to be evoked by concurrent alterations in the degree of extension of the trunk on the hips and in the position of the head in space. In leaning forward, as long as the weight of the trunk can be supported by the muscles which extend the trunk on the hips, the posture of the affected upper limb remains flexor. As soon as a point is reached at which the patient must either support part of his weight on the upper limbs, or fall, the affected upper limb becomes extended. The resumption of the erect position from the quadrupedal is brought about by extension of the hips and spine. As the patient becomes erect, the extended upper limb slowly becomes flexed. Thus the extensor posture of the affected upper limb is evoked by flexion of the hips and spine associated with lengthening of the extensor muscles of the hips and the erector spinæ, while the flexor posture is elicited by extension of the hips and spine, brought about by shortening of the muscles.

Impulses from other proprioceptors, however, are of equal importance in evoking the quadrupedal extensor reflex. Thus, in the supine patient, flexion of the hips and spine no longer evokes extension of the affected upper limb, but increases the flexor tonus. It is, in fact, only when the position of the head in space and the posture of the neck are such as are naturally associated with the quadrupedal attitude that flexion of the hips and spine evokes extension of the affected upper limb. In physiological terms, extension of the upper limb is reflexly evoked by impulses derived from the labyrinths and the muscles and joints of the spine and hips. Regarded biologically, it forms part of the quadrupedal posture of the body as a whole.

(2) *Reflex Effects of Flexion of the Lower Limbs in the Erect and Supine Attitudes.*

An increase in the flexor tonus of the affected upper limb is evoked by active flexion of the hips and knees in an erect or supine patient. This is one of the most constant tonic reflexes in hemiplegia. The greater the degree of active flexion of the joints of the lower limbs, the more pronounced is the increase in the flexor tonus of the upper limb. Thus the change from erect standing to erect sitting, with the hips and knees flexed to a right angle, causes a moderate increase; while, if the patient is made to flex his lower limbs still more acutely, until the heels are in contact with the buttocks, the flexor tonus of the upper limb becomes greatly exaggerated. The same progressive increase in the flexor tonus of the upper limb is evoked by active flexion of the hips and knees when the patient is supine. In no case have I been convinced that any change in the tonus of the upper limb resulted from passive flexion of the lower limbs, to however acute an angle. It is suggested that the biological meaning of this tonic reflex is that the increased flexor tonus in the upper limb is the response to the assumption of a sitting or squatting posture.

(3) *Tonic Neck Reflexes.*

The tonic neck reflexes were first described by Magnus and his fellow workers, and are sufficiently familiar to need no detailed description here. Walshe [14] has observed that the same tonic effects of rotation and lateral flexion of the neck may be observed in the flexed upper limb of many hemiplegic patients. I have found that these reflexes are often well marked in the extended upper limb of hemiplegic patients in the quadrupedal posture.

Less attention has been directed to the tonic reflex effects of flexion and extension of the neck in the sagittal plane. Magnus showed that in decerebrate animals extension of the neck led to increase in the extensor tonus of the fore-limbs, while flexion of the neck diminished it. The same reflex can be obtained in the hemiplegic patient in the quadrupedal attitude (figs. 5 and 6). When, however, a hemiplegic patient is in the erect, supine or lateral postures, the effect of extension and flexion of the neck is reversed, extension of the neck leading to increase in the flexor tonus of the affected upper lip, flexion of the neck diminishing the flexor tonus. This observation is confirmed by Simons [11], who has observed the same tonic effects of flexion and extension

of the neck in supine hemiplegic patients. This tonic neck reflex is antagonized to some extent in the erect posture, and still more in the supine, by a tonic labyrinthine reflex to be described in the next section. If the tonic labyrinthine reflex is relatively powerful, the tonic neck reflex may not be elicitable in the supine posture, but it can usually be obtained in the erect and lateral postures.

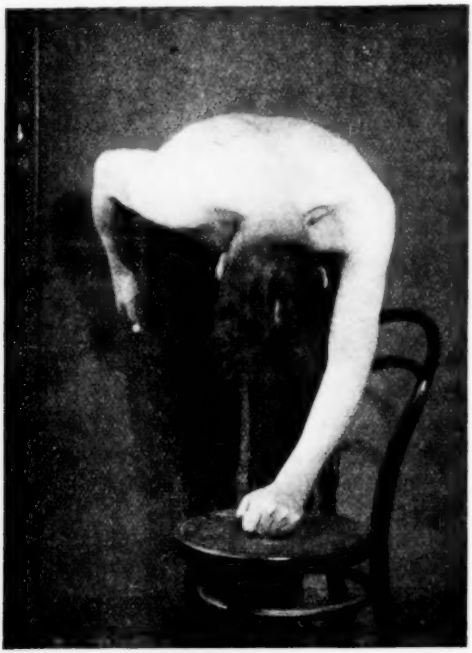

FIG. 5.—Patient (No. 1) suffering from left hemiplegia, in the quadrupedal attitude. Flexion of the neck diminishes the extensor tonus of the affected upper limb.

(4) *Reflex Effects of Changes in the Position of the Body in Space; Tonic Labyrinthine Reflexes.*

The change from the erect to the supine posture has been found in some cases to be associated with a moderate increase in the flexor tonus of the affected upper limb; in others, no change could be detected. The change from the supine to the prone posture is usually associated with an increase in the flexor tonus of the affected upper limb. Still more marked and constant is the difference between the states of the limb in

the two lateral postures. When the affected upper limb is uppermost, its flexor tonus is much greater than when it is below.

Some of these changes have already been described by Walshe [14], who was led to look for them by Magnus's observation that in decerebrate animals the extensor tonus of the limbs varied according to the position of the animal in space. Magnus found that it was maximal in

FIG. 6.—Patient (No. 1) suffering from left hemiplegia, in the quadrupedal attitude. Extension of the neck increases the extensor tonus of the affected upper limb. Compare posture of hand with that of chimpanzee in fig. 2.

the cat when the animal was laid upon its back with the head so that the line of the mouth made an angle of $+45^{\circ}$ with the horizontal. These variations associated with changes in the position of the body in space are determined by impulses from the labyrinths. Walshe found that similar changes in the tonus of the affected upper limb occurred in man in hemiplegia, the flexor tonus being greater in the prone attitude than in the supine. This difference, however, is not to be detected in

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every case. Walshe observed also that the change from the sitting to the supine posture led to an increase in the extensor tonus of the affected upper limb. This change, however, is not the result of labyrinthine impulses alone. Flexion of the hips, as has been shown above, reflexly increases the flexor tonus of the affected upper limb. Extension of the hips, which occurs in the change from the sitting to the supine posture, therefore co-operates with the labyrinthine reflex in evoking an extension of the affected upper limb.

The difference between the states of tonus in the limb in the two lateral postures finds a parallel in the difference observed by Bazett and Penfield [1] in decerebrate animals in similar circumstances. These workers noted that in decerebrate animals lying on their sides the upper fore and hind limbs were relatively flaccid when compared with the lower. It would appear, therefore, that the extensor spasticity was less marked in the limbs of the uppermost side, the side in which in man the flexor spasticity is greater. There is no evidence to show whether this difference is determined by labyrinthine impulses, or by impulses derived from the skin as the result of contact with the surface upon which the individual is lying.

(5) *The Effect of Flexion of the Unaffected Upper Limb.*

When the patient is in the quadrupedal posture, both active and passive flexion of the unaffected upper limb have been found to increase the extensor tonus of the extended upper limb on the affected side. This appears to be an example of the crossed extensor reflex which is found in the spinal dog and in paraplegia in man, and in which reflex flexion of one lower limb is associated with an increase in the extensor tonus of the opposite one.

Conclusions.

What, to use Sir Charles Sherrington's phrase, is the "biological purpose" of the extensor and flexor postures of the upper limb in hemiplegia? To recapitulate, in the extensor posture, which is associated with a quadrupedal attitude, the limb is flexed, adducted and internally rotated at the shoulder, and extended at the elbow. The fore-arm is pronated and the wrist and fingers are flexed. The palm of the hand is thus directed somewhat backwards and outwards. This is the posture of the upper limb described by Wilson [15] as occurring in cases of physiological "decerebration" in man. The following account

is given by Wilson of the posture of the upper limbs during a "tonic" fit. "Both arms became rigid, the left rather more than the right. Both were adducted at the shoulder and strongly extended at the elbow, with pronounced internal rotation and hyperpronation; the wrists were flexed, so that the palms of the hands looked up and out, quite turned away from the body." In other cases described by Wilson, the posture was the same. In one patient, however, the wrist and first and second fingers were extended instead of being flexed. A very similar posture is described by Riddoch and Buzzard [8] as being permanently adopted by the upper limbs in a patient who had received a gun-shot wound which involved the spinal cord in the upper cervical region. The following description is given of the posture of this patient: "He stoops slightly forward with his shoulders drooping, his arms a little in front of his trunk, adducted and rotated inwards at the shoulders, rigidly extended at the elbows, the fore-arms pronated, the hands slightly flexed at the wrists, the fingers extended at the metacarpo-phalangeal joints and flexed at the interphalangeal joints, with hyperextension of the last phalanx of the thumb."

Wilson first pointed out that this extensor posture of the upper limb resembles in general the posture of the fore-limb in the decerebrate animal, as described by Sherrington. Sherrington [9] writes: "The animal on being suspended hangs with its fore-limbs thrust backwards, with retraction at shoulder-joint, straightened elbow and some flexion at wrist. The hand of the monkey is turned with its palmar face somewhat inward." In spite of differences of detail, it is clear that the extended posture of the upper limb during tonic fits in man is essentially similar to the posture of the fore-limb in the decerebrate animal. This, as Sherrington has shown, is reflex quadrupedal standing. The same significance, it is here contended, is to be attributed to that extended posture of the upper limb in hemiplegia which is evoked by the quadrupedal extensor reflex.

This view is supported by the fact that this extensor posture is modified in the same way by tonic neck reflexes as the extensor posture of the fore-limb in a decerebrate animal. Further, increase in the tonus of the extensors in the affected upper limb in a patient in the quadrupedal posture has been observed to follow flexion of the opposite upper limb. This reflex is familiar in the spinal animal and also in the lower limbs in paraplegia in man as the crossed extensor reflex. Not only does the posture of the upper limb evoked by the quadrupedal extensor reflex in hemiplegia resemble in all these features

the posture of the fore-limbs described by Sherrington as reflex quadrupedal standing, but it is evoked by those very changes in the posture of the body which are associated with the change from the erect to the quadrupedal posture. All these considerations appear conclusive that this is indeed its significance.

Perhaps the most striking and suggestive confirmation of this contention is that the hemiplegic patient in the quadrupedal posture, resting on the flexed digits of his extended upper limb, is reproducing the habitual standing and walking posture of the fore-limb in the anthropoid ape. This is a point of considerable interest and importance. Monkeys, unlike anthropoid apes, walk on the palmar surfaces of the hands. Man tends to adopt the same posture if he goes down on all-fours. To rest upon the dorsal surfaces of the flexed digits is thus a posture peculiar to anthropoids. It is this attitude, which is probably that of his most recent quadrupedal ancestor, that characterizes the extended upper limb in hemiplegia and the "decerebrate" posture in man. Here, perhaps, we may find an explanation of a significant difference in detail between the posture of the fore-limb in the decerebrate monkey, as described by Sherrington, and the homologous posture in man. In the monkey, the hand "is turned with its palmar face somewhat inward." In man, both in the quadrupedal extensor posture, and in the posture occurring in "tonic" fits, the palm of the hand is turned away from the body, the knuckles being directed inwards. The part turned towards the body in man is thus, as regards quadrupedal standing, the functional anthropoid equivalent of the monkey's palm.

We are now in a position to regard the flexor posture of the upper limb in hemiplegia from a new point of view. If the hemiplegic patient assumes a quadrupedal attitude, the flexed upper limb becomes extended: when he stands erect again, it once more becomes flexed. Hence the flexor posture may be considered as a modification of the extensor evoked by the assumption of an erect attitude. Thus clinical observation supports the hypothesis suggested by a study of phylogeny. It may be objected that the upper limb remains flexed though the patient adopts other postures, for example, lies prone or supine. This is true, but the fact that the extensor hypertonia of the lower limb persists in these attitudes has never been held to invalidate the view that its extensor posture is essentially related to standing. It may be that the flexor posture of the upper limb in the prone or supine hemiplegic has a different biological meaning from that of the same posture

when he is erect. But, in view of the fact that the extensor hypertonia of the lower limb persists equally during lying, it seems more probable that it has not. Magnus [5] has shown that in the decerebrate animal the extensor tonus of the limbs is greatest when the animal is supine and the line of the mouth at an angle of 45° above the horizontal, the attitude in which the posture of reflex standing would appear most useless. Some inappropriateness of response to postural change is not a surprising result of the disintegration which must follow such a lesion as leads to hemiplegia.

The quadrupedal extensor reflex and its reversal, however, are not the only evidence afforded by clinical investigation in support of the view that the flexor posture of the affected upper limb in hemiplegia is related to the erect attitude. Further confirmation of this hypothesis is to be found in the nature of the changes of posture of other parts of the body, which lead to an increase in the flexor tonus of the affected upper limb. It is of especial interest that the flexor tonus should constantly be augmented by flexion of the knees and hips, this effect being most marked in the erect squatting posture. For it will be remembered that the erect resting attitude in anthropoids and monkeys, with which the flexor posture of the fore-limbs is associated, is a squatting one in which the hips and knees are acutely flexed. It is surely significant that the greatest intensification of the flexor tonus of the upper limb in hemiplegia should be evoked by the adoption of the simian resting attitude. Of considerable interest also is the reversal of certain tonic neck reflexes in the affected upper limb by the assumption of the erect posture. Rotation and lateral flexion of the head have been found to produce the same effects in the upper limb in hemiplegia whether the patient is in the erect or quadrupedal attitude. This is not the case with the tonic reflex effects of dorsi- and ventroflexion of the neck. When the patient is in the quadrupedal attitude, dorsiflexion of the neck leads to an increase in the extensor tonus of the affected upper limb. This is the effect produced in the fore-limbs in all decerebrate animals and forms part of the modification of the posture of the body which is associated with an upwardly directed gaze. Similarly, both in animals and in the hemiplegic patient in the quadrupedal posture, ventroflexion of the neck leads to a diminution in the extensor tonus of the fore-limbs. When, however, the hemiplegic patient is standing erect or lying in the supine or lateral postures, dorsiflexion of the neck increases the flexor tonus of the affected upper limb and ventroflexion diminishes it. In these attitudes, dorsiflexion of the neck

no longer has the same meaning as in the quadrupedal animal, and its influence on the flexor tonus of the upper limb is the same as that of extension of the hips and of the rest of the spine. All these considerations point to the conclusion that the resemblance between the posture of the upper limb in hemiplegia and the resting posture of the simian fore-limb is not fortuitous. A lesion of the human pyramidal tract in proportion as it abolishes the capacity for voluntary activity in the upper limb " releases " an ancestral posture, a simian attitude which is modified reflexly by changes in the posture of the whole body in a fashion appropriate to the needs of an anthropoid ape.

But in all anthropoid apes and monkeys the flexor posture of the fore-limbs is part of a squatting resting attitude and is associated with flexion of the hips and knees. How are we to interpret the association in hemiplegia of a flexor posture of the upper with an extensor attitude of the lower limb? It is, of course, possible that this relationship possesses no significance, that, as a result of the disintegration following a pyramidal lesion, postures appear in the upper and lower limb which are entirely unrelated. This would be the case if the posture of the upper limb were related to prehension and that of the lower were locomotor. But all the evidence put forward in this paper appears to indicate the closest possible relationship between the postures of the upper and lower limbs in hemiplegia. Indeed, we have reached the conclusion that in some circumstances the relationship of the postures of each limb is that of parts of an integrated whole. Such has seemed to be true of the quadupedal and of the erect squatting attitudes. It seems justifiable, therefore, to seek an equal significance, for the association of the flexed upper with the extended lower limb in hemiplegia, speculative though such an explanation must necessarily be.

Little light has yet been thrown upon that critical step in human evolution when the giant anthropoid ancestor of man abandoned the support of his fore-limbs and walked erect. In this connection it is interesting to consider the gait of the gibbon. When on the ground it habitually walks erect, with the fore-limbs adducted and externally rotated at the shoulders, flexed to an obtuse angle at the elbows and acutely flexed at the wrists. It thus employs its long fore-limbs in the manner of a tight-rope walker to preserve its balance. This is the gait of an animal comparatively ill-adapted to an erect posture. The anatomical changes which have taken place in the course of evolution from the hylobatian to the human have been, as Keith shows, in the direction of making a stable erect posture possible with a minimum of

muscular work. There is no necessity for man to use his arms for balancing except when he slips. This increased stability in the erect posture is in process of attainment in the giant anthropoids. May we not suppose that the plantigrade stage in human evolution was reached with the development of a giant anthropoid that was able to stand erect with arms, now required neither for balance nor support, in the flexor resting posture? If this view be justified, we have found a possible explanation of the association in hemiplegia of the flexed upper with the extended lower limb. This, it is suggested, is the primitive human standing attitude. Sherrington has shown that decerebate rigidity is reflex quadrupedal standing. In the same way the facts we have considered would seem to suggest that the hemiplegic posture should be regarded as reflex erect standing.

I am greatly indebted to Sir Charles Sherrington for his kindness in giving me information concerning the occurrence of flexor postures of the fore-limbs under experimental conditions in animals.

APPENDIX.

Reports of Cases.

No. 1.

Previous history.—Frederick B. was a well-developed, muscular man, aged 39. In 1907, while in the Army in India, he "had a stroke," which left him with an almost complete paralysis of the left upper limb and some weakness of the left lower limb. He had previously contracted gonorrhœa, but denied having had a chancre. In 1924 he began to suffer from generalized epileptiform convulsions which responded to treatment with luminal and bromide. His mother's twin brother was epileptic. He had been married two years and had had one child.

General condition.—He was an intelligent man and co-operated readily in the investigation.

The fundi were normal. The pupils were equal and regular, and reacted briskly to light and on convergence. The ocular movements were full and there were no squint, diplopia, ptosis or nystagmus. There was weakness of voluntary movement of the left side of the face, soft palate and tongue.

The right upper limb was normal; the condition of the left will be described below. There was moderate loss of voluntary power in the left lower limb, with some extensor spasticity. The right lower limb was normal. The tendon-jerks were all brisker on the left side than on the right; the abdominal reflexes were diminished on the left side, but normal on the right. The right plantar response was flexor and the left extensor. There was

relative anæsthesia and analgesia on the left side of the body with gross impairment of postural sensibility in the fingers and toes on the left side and complete astereognosis in the left hand.

The blood Wassermann reaction was negative. Examination of the cerebro-spinal fluid yielded the following result: Wassermann reaction negative: Nonne-Apelt, negative; protein 0·035 per cent.; cells 1-2 per c.mm.; Lange negative.

Condition of the left upper limb.—Voluntary power: at the shoulder all movements were possible, though feeble, the strongest being adduction; there was slight power of flexion and extension of the elbow, flexion being stronger than extension. Extension of the wrist was extremely feeble, being insufficient to bring the dorsum of the hand into line with the fore-arm. Extension of the fingers was absent. Slight power of flexion of the wrist and fingers remained.

The quadrupedal extensor reflex.—The usual posture of thelimb was that characteristic of hemiplegia. It was adducted and internally rotated at the shoulder and flexed at the elbow. The fore-arm was semi-pronated and the wrist and fingers were flexed (fig. 3). There was marked hypertonia of the muscles maintaining this posture. If the patient, while standing or kneeling, were made to lean forward to such an extent that he was compelled to support his weight partly with his upper limbs, the paralysed upper limb assumed a new posture. It became flexed at the shoulder, and still more strongly adducted and internally rotated at this joint. At the elbow flexion gave place to extension. The pronation of the fore-arm became increased. The wrist, flexed at first, became extended as soon as the weight was taken by the limb: the fingers remained flexed, the dorsum of the two terminal phalanges being in contact with the surface upon which the upper part of the body was being supported (figs. 4, 5 and 6). This new posture was maintained by an extreme hypertonia of the muscles concerned, especially of the extensors of the elbow. This was sometimes so great that it was impossible passively to flex the joint.

Effect of flexion of the hips and knees in the erect and supine attitudes.—Active flexion of the hips and knees led to an increase in the flexor tonus of the affected upper limb, so that the change from erect standing to erect sitting, and from this to an erect squatting posture, was marked by a progressive increase in the flexor tonus of the limb. The same tonic effect of flexion of the hips and knees could be observed when the patient was lying supine. Passive flexion of the lower limbs was without effect on the tonus of the affected upper limb.

Tonic neck reflexes.

(*a*) Rotation and lateral flexion of the neck.—Rotation and lateral flexion of the neck towards the affected side diminished the flexor tonus of the affected upper limb; rotation and lateral flexion to the sound side increased it. The same tonic effects were produced in the extended upper limb when the patient was in the quadrupedal posture.

(*b*) Ventro- and dorsiflexion of the neck.—When the patient was in the quadrupedal posture, ventroflexion of the neck diminished the extensor tonus

of the affected upper limb, dorsiflexion of the neck increased it. When the patient was in the erect, supine or lateral postures, the reverse effect was produced, dorsiflexion of the neck increasing the flexor tonus of the limb, ventroflexion diminishing it. This effect was confirmed by the nature of the associated movements elicited when the neck was in the positions of ventro- and dorsiflexion. When the patient was standing with the head thrown back, strong voluntary flexion of the fingers of the right hand evoked flexion of the left (affected) upper limb; when the head was thrown forward, flexion of the fingers of the right hand evoked extension of the left upper limb.

Effect of changes in the position of the body in space.—The change from the erect standing to the supine attitude led to an increase in the flexor tonus of the affected upper limb. The change from the supine to the prone attitude produced no appreciable change in the tonus of the limb. In the lateral position with the affected side uppermost, the flexor tonus of the affected upper limb was considerably greater than in the opposite lateral position, with the affected side below.

Effect of flexion of the normal upper limb.—When the patient was in the quadrupedal posture, both active and passive flexion of the normal upper limb led to an increase in the extensor tonus of the affected upper limb.

No. 2.

Charles P., aged 60, one year previous to examination suddenly lost power in his left upper and lower limbs. Consciousness was said to have been retained. Some recovery of power occurred in the lower limb, but none in the upper. There was nothing of importance in the previous history. The patient was a fairly intelligent plethoric-looking man, with a blood-pressure of 200/110. The fundi showed moderate retinal arteriosclerosis. The pupils and cranial nerves were normal, except for weakness of voluntary movement of the lower part of the face on the left side.

The left upper limb is considered below. The right upper and lower limbs were normal. There was considerable loss of voluntary power in the left lower limb which exhibited marked extensor spasticity with ankle clonus. The tendon-jerks were all exaggerated on the left side and normal on the right; the abdominal reflexes were present on the right side and absent on the left. The right plantar reflex was flexor, the left extensor. There were relative anæsthesia and analgesia over the left side of the body with relative loss of postural sensibility in the fingers of the left hand and the toes of the left foot. The Wassermann reaction in the blood was negative.

Condition of the left upper limb.—The left upper limb was maintained in a position of adduction and internal rotation at the shoulder, flexion at the elbow, pronation, and flexion of the wrist and fingers. There was very marked flexor spasticity. Voluntary power was almost completely lost in the limb. There was no movement possible at the shoulder or the elbow, and below this joint only very feeble flexion of the wrist and fingers.

Quadrupedal extensor reflex.—The patient, kneeling upon the bed, was made to lean forwards and allowed to support his weight with his right upper limb. The left (affected) upper limb now assumed a new posture. Internal rotation at the shoulder became greater, the elbow became extended, pronation was increased and the wrist and fingers remained flexed. The limb was now rigid in extension and could only be passively flexed with the greatest difficulty. The patient's general condition did not allow of the observation of other tonic reflexes in the affected upper limb.

No. 3.

Henry C., aged 29, two years previous to examination contracted syphilis, for which he received treatment. Three weeks before admission to hospital he developed weakness of the right upper and lower limbs, together with loss of speech. When examined he was dysphasic. His pupils were equal and regular, but the reaction to light was unequal, the left reacting more briskly than the right; both reacted well on convergence. Ocular movements were full and there were no squint, diplopia, ptosis or nystagmus. There was weakness of the lower part of the face and the soft palate and tongue on the right side. The condition of the right upper limb is separately described below. In the right lower limb there was considerable loss of voluntary power with well-marked extensor spasticity. The left upper and lower limbs were normal. The tendon reflexes were all brisker on the right than on the left side; the abdominal reflexes were diminished on the right; the right plantar reflex was extensor and the left flexor. There was no sensory loss. The Wassermann reaction in the blood was strongly positive. In the cerebro-spinal fluid the Wassermann reaction was strongly positive; Nonne-Apelt, positive; protein 0·090 per cent.; cells 67 per c.mm., type lymphocytes; Lange 0000111000.

Condition of the right upper limb.—The right upper limb was in a position of adduction and internal rotation at the shoulder, flexion at the elbow, pronation and flexion of the wrist and fingers; and exhibited a well-marked hypertonia of the muscles maintaining this posture. Voluntary power was very much reduced, the strongest movement being flexion of the elbow.

The quadrupedal extensor reflex.—To elicit this, the patient was made to kneel upon the bed and lean forwards. The hypertonia of the flexors of the elbow previously present entirely disappeared and was replaced by a moderate extensor spasticity, the limb assuming a posture of internal rotation and adduction at the shoulder, extension of the elbow, pronation and flexion of the wrist and fingers.

Effect of flexion of the hips and knees in the supine posture.—Active flexion of the hips and knees, when the patient was supine, evoked a well-marked increase in the flexor tonus of the affected upper limb. No change in the flexor tonus was noted as a result of passive flexion of the lower limbs. The change from the sitting to the supine posture led to a diminution in the flexor tonus, the limb assuming a more extended posture.

Tonic neck reflexes.—In both the erect sitting and supine attitudes extension

of the neck was observed to lead to an increase in the flexor tonus of the affected upper limb; flexion of the neck to a diminution in the flexor tonus.

Effect of changes in the position of the body in space.—The change from the supine to the prone posture did not produce any detectable change in the tonus of the affected upper limb. When the patient was in the lateral position with the affected side uppermost, the flexor tonus of the upper limb was much greater than when he was in the lateral position with the affected side below.

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ON THE METHODS OF EXAMINING THE CONDITIONED FOOD REFLEXES IN CHILDREN AND IN MENTAL DISORDERS.

BY A. G. IVANOV-SMOLENSKY, M.D.

Lecturer on Psychiatry in the Military Medical Academy and Professor in the Hertzen Institute, Leningrad.

THE work on "Conditioned Food Reflexes in Children" was begun in Russia twenty years ago by N. I. Krasnogorsky, one of Professor Pavlow's pupils.

Krasnogorsky studied the conditioned motor reflexes in the form of opening the mouth and swallowing after associating different optic, acoustic and skin signals with feeding.

He mainly examined small children. Lately, Miss E. Mateer, an American, has made use of Krasnogorsky's method on a great number of children.

In the course of the last two years the following methods for the study of conditioned motor reflexes in children, aged 5 to 12, have been applied in my laboratory at the Hertzen Pedagogical Institute, and also at the Military Medical Academy:—

Through a wall of the experimental room in which the person to be examined is placed, a sloping metal tube is constructed (length 55 cm., diameter 3 cm.), NN' (fig. 1).

On the side of the experimentater the slide is closed by a simple photographic shutter which is connected: (1) with a signal (D); and (2) with a rubber bulb (R). By pressing this bulb the experimentater opens the upper aperture (a) of the tube NN'; at the same time the shutter puts the signal into action, and thus the moment of opening can be registered on the kymograph.

In front of the opening there is a small sloping shelf (L) on which the experimentater places a piece of chocolate. When the shutter opens the chocolate falls into the tube and quickly moves to the lower opening (a'). Here also there is a photographic shutter which is opened by a rubber bulb (R'); the latter is held by the person being examined; it is connected not only with the shutter but also with a Marey tambour (M), and when the person being examined presses the bulb to open the shutter that movement is registered on the kymograph by a manometer, or by a special apparatus which indicates the force of the motor reflex of the hand.

The upper wall of the metal tube in its lower third has a glass plate (*V*), allowing the person that is being examined to see the moving chocolate. In front of the lower opening of that slide there is a metal saucer, upon which the chocolate falls when the shutter is opened.

Fig. 1 is a drawing of this apparatus.

The experiment is made in the following way: The child sits in front of the lower shutter of the apparatus in such a manner that he faces the glass part of the tube with the rubber bulb (R) in his hand. While the chocolate is moving in the tube past the glass (V), the experimentater presses the child's hand and thus also the bulb held in his hand. Having done so several times he succeeds in teaching the

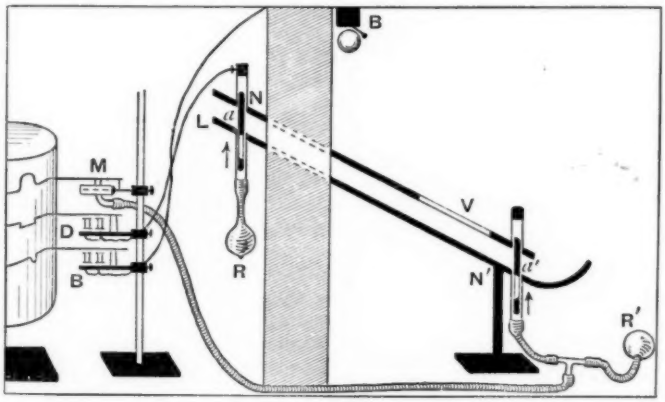

FIG. 1.

child to press the bulb every time he sees the chocolate in the tube. The chocolate when it falls into the saucer is at the disposal of the child and the latter eats it at once.

When the child has become accustomed to deal with the apparatus, the experimentater begins to form the grasping conditioned reflex (as squeezing) to a bell, to the lighting of an electric lamp, to some tactile stimulation, &c. For instance, after having started the ringing of an electric bell, two or three seconds later he adds a food stimulus to the sounding of the bell by opening the upper shutter and allowing the chocolate to slide down, which the child receives by opening the lower lock.

After several times ringing the bell and giving food simultaneously, a motor reaction (pressing on the bulb) is noticed in response to

the sounding of the bell, i.e., a conditioned motor reflex has been formed. The latent period of the seizing reflex is measured either by means of a stopwatch, or when a kymograph can be applied by means of a Jaquet chronograph.

The intensity of the conditioned reflex (the force applied by the child in squeezing the bulb) is registered in the above-mentioned way by a manometer, or by means of a Marey drum and a kymograph. The conditioned signal and the feeding are registered by a Deprez signalizer.

Records of conditioned (bell) and unconditioned (food) reflexes with the responsive reactions of the child are found in the following diagram (see fig. 2).

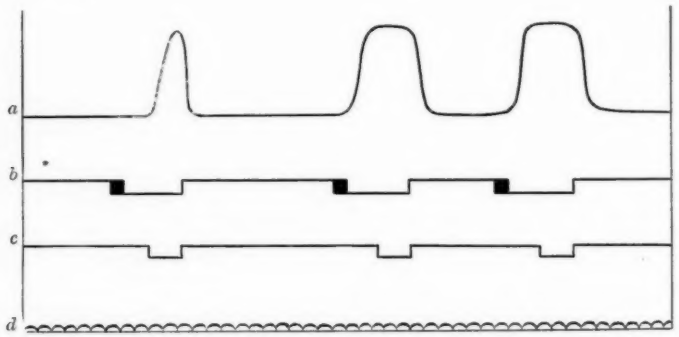

FIG. 2.—*a*, Conditioned motor reflex. *b*, Conditioned stimulus (bell). *c*, Food stimulus (chocolate). *d*, Time register.

The intervals between the single stimuli (bell, feeding) were varied in duration from 0·25 to 2 minutes.

If, after having established a conditioned reflex, we apply several times the conditioned stimulus (bell) without feeding, the latent period begins to increase gradually, the intensity of the reflex (i.e., the force of pressure on the bulb) decreases and finally the reflex disappears, i.e., the conditioned reflex is extinguished.

When the conditioned reflex to bell A had been formed, we generally, in consequence of the process of generalization, obtained the same reaction to other bells: B, C, D. If every time while feeding with bell A we applied from time to time bell B, always without accompanying the latter by feeding, we soon attained differentiation: A produced a conditioned reflex, while B destroyed it, i.e., an inhibitory effect was produced (a negative or inhibitory conditioned reflex).

If we combined every time the sounding of an electric bell with feeding, while a combination of that bell with the switching on of an electric light was not accompanied by a gift of chocolate, we transformed the electric lamp into a conditioned inhibitor; at the same time the bell ceased to produce a reaction.

By continuing to sound the bell for ten to fifteen seconds (instead of two to four seconds) the reaction was retarded and the conditioned reflex appeared only by the eighth or fourteenth second.

Thus we can study all four kinds of internal inhibition in children: the extinguishing, the differentiating, the conditioned and the retarded inhibition. If we introduced different external stimulations while a certain conditioned stimulation was acting, we could observe conditioned inhibition.

Experiments have been performed in my laboratory (Novikova, Fadeeva, Hackel, Ronczievsky and Aksenov) on the highest nervous activity of children, aged from 6 to 12 years, and on the speed and durability of forming positive and inhibitory conditioned reflexes (i.e., on differentiating, on conditioned inhibition and on delayed reflexes).

These experiments have proved that we can distinguish three groups of children: (*a*) children with a healthy nervous activity in whom positive and inhibitory conditioned reflexes are formed quickly and remain stable; (*b*) children with feeble internal inhibition, i.e., those in whom nervous irritation is predominant; (*c*) children in whom cortical inhibition is more prominent than irritation (Novikova, Bronstein, Hackel).

At present we are investigating the functional value of the cerebral hemispheres, and the peculiarities of age and type of the nervous activity of children aged from 5 to 15 years.

We are now successfully applying the methods described above, as has been proved by experiments, in examining the conditioned reflexes of some categories of individuals in imbecility, mental debility, schizophrenia and general paralysis.

Thus by means of the method here described we can examine the grasping conditioned reflex, which is a reaction of apparently great biological importance.

FORCED GRASPING AND GROPING.

BY W. J. ADIE, M.D., F.R.C.P.
Physician to Out-patients, the National Hospital, Queen Square,
AND
MACDONALD CRITCHLEY, M.D., M.R.C.P.
Registrar, the National Hospital, Queen Square.

MUCH has been written on the manifestations of disease in the frontal lobes, but the diagnosis of frontal tumour is rarely made with the confidence that sometimes attends localization in other regions, because we possess few unequivocal signs of disease confined to this part of the brain; the phenomena we are about to describe, however, were observed in three patients with a tumour of one frontal lobe, and a search for comparable cases observed by others revealed ten like our own, and a larger number in which the same signs accompanied vascular lesions.

In all of these cases the special signs were found in the upper limb of the side opposite to the diseased frontal lobe; in some of the tumour cases they were, for a time, the only focal signs; we are convinced, therefore, that their presence in a patient with a cerebral tumour is unequivocal evidence of the situation of the tumour, and the main object of this communication is to draw attention to their value for the practical purpose of localization.

DESCRIPTION OF CASES.

Case 1.—Alfred L., aged 54, was admitted to the National Hospital, Queen Square, under the care of Dr. Gordon Holmes, on September 3, 1926. For many years he had suffered from headaches which, however, did not prevent him from doing his work. In July, 1926, he became drowsy and forgetful and began to make errors in his reports. On the night of August 4, 1926, he had a convulsive attack which lasted about twenty minutes. Thereafter he complained of severe headaches, his memory failed rapidly, he became very drowsy and passed urine involuntarily.

His previous health was good; he lost his left eye by accident in childhood; his wife and son are healthy; a child born prematurely died in early infancy.

Condition on admission.—September 3, 1926: He is very drowsy, yawns frequently and falls asleep during the examination. He speaks very slowly, with long pauses, but is not aphasic or dysarthric. His memory for recent and

remote events is very bad; he loses the thread of his narrative and needs much prompting. He knows he is in a hospital but appears to be disoriented in time; there are no delusions or hullucinations; he is right-handed. The upper part of the face is scarred, and the left eyelid is closed over an empty socket.

No detectable anosmia. Vision is $\frac{6}{12}$ in the right eye; the fundus is normal, and the visual field is full; there are signs of old injury to the cornea and iris, but the pupil reacts briskly and the eye moves well in all directions. Sensation on the face is normal; the muscles of mastication are healthy. There is slight weakness of the left side of the face, more obvious with volitional than emotional movements; it is difficult to persuade him to carry out movements correctly, e.g., when told to shut his eyes he sometimes opens his mouth and puts out his tongue. Hearing is normal; there is no difficulty in swallowing, the palate moves well on phonation; the tongue is protruded well; it shows no fibrillation or tremor.

Motor system.—There is nothing unusual in the attitude of the limbs at rest; tone and nutrition normal. On holding the arms outstretched the left falls slowly; the right arm shows at times a coarse irregular tremor.

The range of voluntary movements at all joints is complete; the power is good on both sides, perhaps slightly greater right than left; when told to touch his nose and the observer's finger alternately, he does it well on the right side, but slowly though accurately and steadily on the left.

If a finger is placed lightly within his left palm, his fingers at once make a slow, clasping movement which he is unable to prevent; if the observer now attempts to withdraw his finger, it is firmly clasped by a rapid movement which increases in power as more force is used to overcome it, and persists for from twenty to forty seconds in spite of efforts to relax; after the finger has at last been withdrawn the hand opens and closes slowly several times. This grasping reflex is elicited every time the palm is touched; the best stimulus is a moving contact over the palmar surface of the metacarpo-phalangeal joints. This phenomenon is not present on the right side.

Forcible flexion of the proximal phalanx of a finger on the palm produces a normal adduction movement of the thumb on the right side (Mayer's reflex). On the left side the reflex is greatly exaggerated, and it can be elicited by gentle flexion of distal joints. Leri's fore-arm phenomenon is present and equal in the two arms.

He is unable to stand without support. In attempting to get into bed he remains on his hands and knees facing the foot of the bed and scratches his head in perplexity, not knowing what to do next. He can carry out the movements of saluting, blowing a kiss, &c., with each hand, and employs a key, a hammer and a pencil correctly in dumb show, but the movements are slow and hesitating. He succeeded in extracting a match with his right hand from a box held in his left but could not strike it; when it was kindled for him he could not light his cigarette. Further tests confirmed the presence of apraxia on both sides, left more than right.

The attitude, nutrition and tone of the lower limbs are normal. The range

and power of voluntary movement is good, but all movements are slow on the left side, and it is difficult to persuade him to exert his strength on this side. All forms of sensory stimuli are correctly appreciated. The tendon and periosteal reflexes are moderate and equal on the two sides; there is no ankle-clonus; the abdominal reflexes are absent. The nature of the response on stimulation of the sole is doubtful. X-ray of skull: no abnormality.

There is no sign of disease in parts outside the nervous system. Blood-pressure 125/85; blood-urea 20 mg. per cent.; Wassermann negative in blood and cerebro-spinal fluid; cerebro-spinal fluid clear, colourless. No cells, total protein, 0·065 per cent. Nonne-Apelt and Pandy reactions very weakly positive.

While in hospital his mental and physical defects varied in severity from time to time.

September 8, 1926: Patient is now doubly incontinent. The tongue deviates slightly to the left; the arm-jerks are brisker on the left side; the abdominal reflexes can now be elicited on both sides, but with greater ease on the right; the right plantar response is flexor, the left doubtfully extensor.

The left grasp reflex is still present.

When tested with a revolving drum, normal optic nystagmus occurs when the drum is rotated clockwise. No nystagmus on anti-clockwise or on vertical rotation.

September 9, 1926: The patient is semi-conscious, can just swallow fluids.

Has a complete left flaccid hemiplegia.

The grasp reflex is almost absent; only by vigorous rotating of the fingers within the patient's palm can the reflex be elicited.

September 11, 1926: Semi-conscious; lies with his right eye deviated to his right. The pupil is small but reacts to light.

The left hemiplegia is unchanged.

The left grasp reflex and the left Mayer's reflex *are both unobtainable.*

Abdominal reflexes absent.

Tendon-jerks present, both plantar responses are extensor in type.

Later in the day he protruded his tongue on command. Could not draw back his tongue but let it remain beyond his teeth.

September 12, 1926: Replied to questions.

The grasp reflex is feebly present in the left hand.

September 13, 1926: Much brighter to-day. Replies to questions.

He still has a left hemiparesis, but there is a good deal more power in that side. Tongue deviates to the left on protrusion. Both plantar responses are extensor in type.

The grasp reflex is still present on the left side.

Mayer's reflex absent on the left side,

September 16, 1926: Coma.

September 18, 1926: Died without regaining consciousness.

The cranial contents were examined six hours after death. The meninges were healthy, the right hemisphere was bulkier than the left. The convolutions

were broadened and flattened. No tumour was visible; the corpus callosum appeared normal. On palpation it was obvious that a hard tumour lay in the depths of the right frontal lobe. The brain was hardened for fourteen days in 10 per cent. formol solution before being cut.

After the brain had been sufficiently fixed the hemispheres were dissected off. No abnormality whatever could be detected in the corpus callosum.

Coronal sections were made through the right frontal lobe, each section being 5 mm. in thickness. A large tumour was seen occupying most of that lobe, extending throughout the white matter to a point immediately in front of the precentral convolution. The neoplasm was hard, firm and definitely circumscribed anteriorly, but posteriorly there was much infiltration of the brain and several areas of cystic degeneration were present. Although the corpus callosum itself was not affected, the callosal fibres were obviously infiltrated throughout their intrafrontal course.

Histological examination of the tumour showed that it was a glioma.

Sections through the other parts of the brain revealed a dilated left lateral ventricle. There was a recent hæmorrhage in the anterior and mesial portion of the pons which was probably the immediate cause of death.

In this case a tumour in one frontal lobe gave rise to reflex grasping and other involuntary movements in the limb of the opposite side; these phenomena, which will be described in more detail later, were present before weakness or any other sign of damage to the pyramidal tracts could be detected; the patient was not conscious of them; after his attention was drawn to them he was unable to prevent them. They were most evident while power in the affected limb was still unimpaired; they disappeared with the onset of severe paralysis but returned in lesser degree with partial return of power.

The patient was apraxic in both limbs, but this, as we shall see later, played no part in producing the other symptoms. Further, Mayer's finger-thumb reflex was greatly exaggerated on the affected side before pyramidal signs appeared. We are not concerned with this reflex here, but we cannot dismiss this important feature without comment. Bilateral exaggeration of this reflex has been seen in diffuse cerebral lesions, e.g., in meningitis, but unilateral exaggeration is rare; so far as we know, the only cases on record are two of Mayer's and one of Stiefler's [9]; in these, as in our own case, a tumour was present in the opposite frontal lobe.

Case 2.—H. C., aged 47, was admitted to the National Hospital, Queen Square, under the care of Dr. Risien Russell, on April 16, 1925. He complained of throbbing headaches with nausea and vomiting which had troubled him for five years. One year before he came to hospital he had an attack,

ushered in by giddiness and a feeling of uselessness in the right leg, ending in unconsciousness; on recovering he found that he was unable to move the right arm and leg; power returned completely during the following two weeks. A month later he had a similar attack with more rapid return of power. Since then he has had frequent attacks without loss of consciousness, in which a feeling of pins and needles begins in the fingers on the right side and spreads up the arm to the lips. For two months he has noticed weakness in the right arm and leg which increases temporarily after each attack. The special senses were not affected and no intellectual or temperamental changes were noticed. His previous health was good. Examination revealed signs of a slight right-sided hemiparesis.

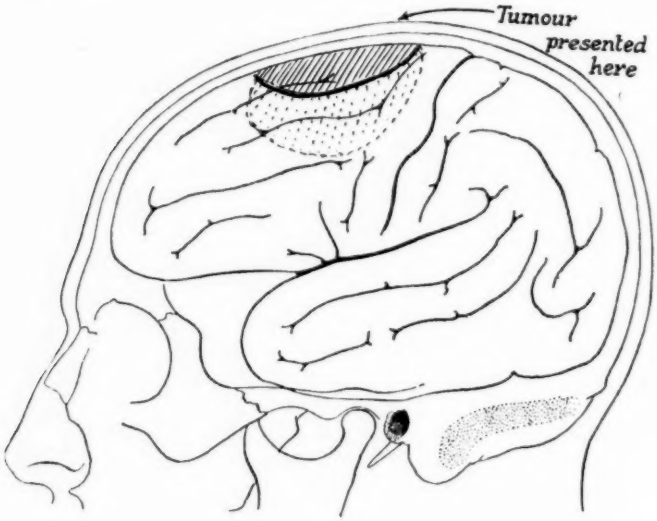

FIG. 1.

On May 6, 1925, Mr. Armour exposed a tumour at the summit of the left precentral gyrus; it was attached to the falx and displaced the frontal lobe without infiltrating it (see fig. 1). The tumour, an endothelioma, was almost as large as a billiard ball and weighed 90 grm. Post-operative recovery was rapid, and six weeks later the man returned to work as a bricklayer. During the next fifteen months he had several sudden attacks with loss of consciousness from which he recovered rapidly and completely.

On October 2, 1926, he was readmitted to hospital complaining of a new kind of attack in which the right arm "went stiff and lifted itself." These attacks, which occurred every ten minutes or so, started with a feeling of pins and needles in the right shoulder; the limb then went into tonic spasm with

the fist closed, the elbow extended and the arm abducted; the head flexed and the eyes deviated to the left side. Consciousness was retained throughout the attack, which lasted from one to two minutes.

Apart from a very slight right hemiparesis, most evident in the lower part of the face and the shoulder, there were no signs of disease in the nervous system or elsewhere. *If, however, an object was placed in the right palm the fingers closed upon it slowly; if an attempt was made to withdraw the object the grasp tightened promptly.* When he was ordered to flex and extend the right elbow, there was a definite delay in beginning each movement owing to an involuntary contraction of antagonistic muscle groups.

October 22, 1926: After taking luminal for some days the spasms in the arm ceased. Muscular power is now equal on the two sides, likewise the tendon reflexes. Mayer's reflex is present on both sides, but the movement of the thumb is slow and weak on the right side. He can open and close the empty right fist repeatedly and promptly; there is no delay or difficulty with rapid alternating flexion and extension of the elbow.

If an object is placed lightly upon any part of the palmar surface of the hand, the fingers move to grasp the object; the movement is not steady but is interrupted by pauses and partial re-extension of the fingers. An attempt to withdraw the object causes the fingers to close upon it firmly, and the grasp becomes more powerful as the observer exerts more strength to overcome it. The forcible closure of the hand is maintained as long as efforts are made to withdraw the object; the grasp relaxes when they cease.

In spite of obviously genuine efforts to open the hand he is unable to do so; when attempts are made to open the right hand an associated extension of the fingers and abduction of the thumb occurs in the normal left hand. When at last the examiner has succeeded in withdrawing the object, the hand opens partly but still maintains a grasping attitude, and the fingers make slow alternating movements of flexion and extension. If, when the patient's eyes are closed, the palmar surface of the hand or fingers is touched lightly, the hand at once assumes the grasping attitude, and moves toward the stimulus; thus, by repeated touches, the hand and arm may be drawn in any direction as if by a magnet.

Progress.—The palmar grasp reflex gradually became more and more difficult to elicit; for the last two weeks of his stay in hospital he remained well and free from seizures. At the time of his discharge the grasp reflex was no longer demonstrable, and there was no evidence of hemiparesis.

In this case reflex grasping and groping were present when power in the limbs was unimpaired. It is important to note that this patient was in no way apraxic. The occurrence of tonic innervation in the right upper arm muscles is also of considerable interest; this was present for a few minutes after each of the Jacksonian fits that occurred during the days following his second admission to hospital; it disappeared with the cessation of the fits and did not recur.

The original lesion was at the upper and posterior angle of the left frontal pole; we infer, therefore, that the lesion responsible for the symptoms we observed some time after the tumour had been removed was also in this region.

Case 3.—Clara B., aged 37, was admitted to the National Hospital, under the care of Dr. Hinds Howell, on August 16, 1926. Her illness began two months before with headache, vomiting and failing memory; a month before admission she had a generalized convulsion. Her previous health had been good; she stated that the left arm and leg had been "awkward and different from the others" since the age of 3 years.

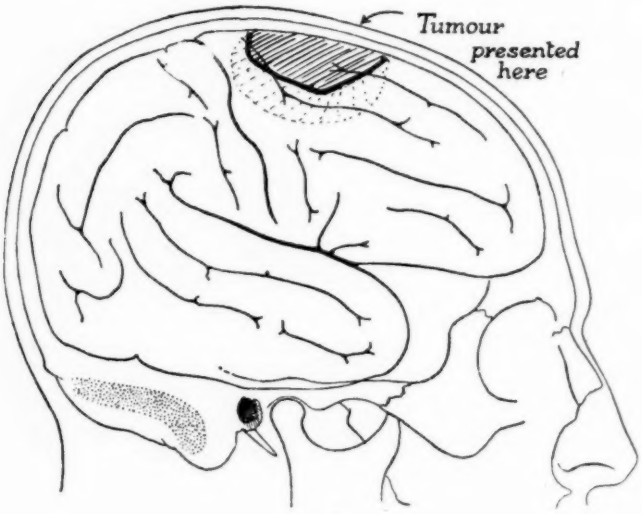

FIG. 2.

Mentally she was dull and apathetic; there was no aphasia or apraxia. Vision was normal but the edges of the discs were slightly blurred; normal optic nystagmus was obtained with a revolving drum. There was slight weakness of the lower part of the face on the left side, otherwise the cranial nerves were normal. The whole of the left side of the body was smaller and weaker than the right; there was no disorder of sensation; the tendon reflexes were brisker on the left side than on the right; the abdominal reflexes were present and equal on the two sides; the left plantar response was extensor, the right flexor. Mayer's reflex was normal on the right side but exaggerated on the left side.

While in hospital her mental condition deteriorated; she became childish, facetious, euphoric and untidy in her habits. *It was noticed that when she was*

lying quietly in bed she always clutched the bedclothes with her left hand. In reply to questions she stated that she was unable to relax her grasp upon objects once she had taken them in her left hand. "When I try to use a knife and fork, I cannot let the fork go when I want to. Sometimes I get hold of the tablecloth and cannot let go. Once I pulled the cloth right off the table that I had just laid."

On applying appropriate tests it was found that the left hand closed upon any object placed within it with a grasp that increased in power with increasing efforts on the observer's part to withdraw the object. After the object had been forcibly withdrawn, the hand continued to make slow grasping movements. A slight touch on the finger-tips caused the hand to place itself in a suitable attitude for grasping the object that touched it, and if the stimulus was repeated the hand moved in the direction of the stimulus and could thus be caused to follow the observer's finger in any direction he desired. If the observer grasped the patient's normal right hand, her left hand moved across and came to rest on the examiner's hand. If she attempted to feed herself with the right hand, the left hand persisted in grasping the utensil also.

On October 29, 1926, Mr. Donald Armour exposed a glioma in the right frontal lobe. It presented at the foot of the first frontal convolution and extended downwards and forwards (see fig. 2).

In this case reflex grasping and groping occurred in a slightly paretic but eupraxic limb. As in our first case, Mayer's reflex was exaggerated in the hand that showed the grasping reflex, that is, on the side opposite to a frontal tumour. The most curious feature of this case was the involuntary and apparently unpreventable intrusion of the affected hand when movements were performed with the normal hand.

Forced Grasping and Groping.

The feature common to these cases is the presence of involuntary grasping and groping movements in the limbs on the side opposite to the frontal lobe in which a tumour was found. We shall now describe these movements in more detail.

(1) A light moving stimulus, such as a stroke with the observer's finger across the palmar surface of the finger-tips, causes the fingers to make a slow grasping movement; this is most obvious in the thumb and index finger. The movement is not one of pure flexion, but that combination of flexion and extension which is appropriate for embracing an object before it is grasped. Sometimes the thumb and forefinger make a definite snapping movement like a crab closing its claws. This reflex is most easily elicited from the palmar aspect of the thumb and index finger; it is most active in response to the first stimulus, but it

may be obtained as often as ten times. This stimulus rarely causes closure of the hand; there is little power in the movement; the fingers may extend again at once or remain for several seconds in the grasping attitude.

(2) Sometimes, as the fingers move into position in response to this stimulus, the fore-arm rotates, or the whole arm moves so as to place the hand in the most favourable position for grasping the object that touched it. At such times, by repeating the stimulus, the hand and arm can be made to move in any direction, as if drawn by a magnet; the appearance is that of a blind man groping for an object.

(3) A light stroke across the palm, preferably at the base of the fingers, causes a more active movement, often complete closure of the hand; this is usually followed at once by complete relaxation if the object used for producing the stimulus eludes the patient's grasp, and the patient makes no voluntary effort to open the hand. Sometimes the fingers make several incomplete grasping movements in response to one stimulus.

(4) If an object is placed at rest upon the open palm the hand closes on it, sometimes very promptly, sometimes slowly, with a grasp that may be light or firm. If the hand has closed firmly on the object, say the observer's fingers, and the patient makes no voluntary effort, it may be noticed that the strength of his grasp waxes and wanes from time to time. The hand usually remains closed as long as it retains the object. If he attempts to open the hand voluntarily he will probably be unable to do so; the more he exerts himself the firmer his grasp becomes. It may be some minutes before he can relax it if he continues to try to do so. Frequently, after a prolonged struggle, the hand relaxes partially as soon as he gives up the attempt to open it voluntarily. The hand closes firmly even when the object grasped causes pain.

(6) If while the patient is grasping an object, maybe quite lightly, the observer makes a gentle effort to withdraw it, the grip tightens promptly and increases in power as the observer uses more and more strength to overcome it; the grasp is so firm that the patient may be lifted from his pillow and dragged across the bed.

(7) When at last the observer has succeeded in freeing the object, the hand may make a slow and fairly full opening movement, "comme pour tâcher d'attraper l'objet fuyant" (Janischewsky), or it may make gentle, incomplete grasping movements that may be repeated several times.

(7) If the patient (third case only) grasps the observer's hand with her healthy hand, the affected hand moves across slowly and grasps it also. The affected hand obtrudes itself persistently and attempts to grasp anything that lies within the healthy hand. (This phenomenon has also been observed by Schuster [15]).

(8) If the patient (third case only) attempts to place an object on the table with the affected hand, when at last she relaxes her grasp and attempts to withdraw she promptly regrasps the object; this is repeated again and again until she gives up the attempt (also observed by van Vleuten [19] and Schuster [15]).

(9) If an object is brought close to the open palm, first on the normal and then on the affected side, the patient being instructed to grasp the object the moment it touches the palm, it will be noticed that the closure is always premature on the affected side. (Also observed by Schuster.)

The findings in the same patient vary from time to time. At one examination all of these signs may be present; at another the hand may show grasping movements or a reflex closure without any persistent contraction; at another the hand may refuse to close in response to stimulation of the palm, although a powerful persistent contraction occurs after the hand has grasped an object voluntarily. The movements occur without the patient's knowledge; after his attention is directed to them he cannot inhibit them. Attempts to force the fingers open after they have closed upon an object are resisted by strong contractions which are only partially overcome by passive flexion of the wrist. While the patient is trying to open his hand synkinetic extension of the fingers of the healthy hand may occur.

Reflex closure of the hand occurs, not only in response to objective testing but also when the patient handles objects voluntarily. He may be able to handle them successfully if he uses his finger-tips only, but, as a rule, anything that touches the palm, feeding utensils, the bedclothes, even parts of the body, are grasped firmly.

Voluntary power in the affected hand may be intact, or show any degree of weakness up to complete paralysis. The signs disappear as paralysis becomes complete, and repeated trials may be necessary to elicit them when power is full; they are most easily obtained when power is slightly but definitely diminished. Patients who are able to open the closed but empty fist with ease may have great difficulty in overcoming reflex closure. Reflex closure may be rapid and very powerful in a limb almost devoid of voluntary power.

Author	Date	Part affected	Pyramidal affection	Apraxia	Nature of lesion	Site of lesion	Remarks
Liepmann ..	1900	L. arm	Slight weakness of L. face and arm	Severe R., slight L.	Vascular	Softenings in left frontal and parietal lobes, also corpus callosum and L. internal capsule	At times "tonic perseveration," at times reflex closure
Steinert ..	1903	R. arm	Progressive R. hemiplegia	?	Glioma	L. mesial gyri anteriorly; corpus callosum from genu almost to splenium; left paracentral lobule and internal capsule compressed	"Involuntary persistence of intentional closure" but probably closure unintentional
v. Vleuten ..	1907	R. arm, slightly in leg	Progressive R. hemiplegia	None R. motor apraxia L.	Sarcoma	L. limbic gyrus including cingulum, and greater part of corpus callosum destroyed; left centrum ovale in front of genu affected. Central and third left frontal convolutions, also radiations, internal capsule and basal ganglia intact	Persistence of voluntary closure and definite impulsive re-grasping
Goldstein ..	1908	L. arm	Slight weakness of L. arm, more of leg	L.	Vascular	Softening of R. gyrus fornicatus, and of white matter, post. end of frontal gyrus, part of cortex and white matter of paracentral lobule and right half of corpus callosum. Basal ganglia intact	Persistence of voluntary closure; involuntary grasping of bedclothes
Noethe ..	1913	R. arm	Severe R. hemiplegia	R. and L.	,,	Large area of softening extending from left frontal pole to the central convolutions; putamen and greater part of globus pallidus also destroyed	Grasped everything that was placed in his hand; grasp increased in power as efforts were made to withdraw
Wilson and Walshe, I..	1914	L. arm and leg	Slight weakness of L. arm, much more of leg	None	Endothelioma	Posterior end of R. superior front gyrus, under mesial gyri at corresponding level, pressing on upper precentral gyrus and L. corpus callosum	Persistence of voluntary closure
Wilson and Walshe, II	1914	L. arm	Slight weakness of L. arm, more of leg	,,	,,	Pressing into posterior ends of R. upper and middle frontal gyri, extending to the anterior margin of fissure of Rolando	Grasp tightened perceptibly on attempting to withdraw object from hand

Bonhoeffer ..	1914	R. arm	Very slight right hemiparesis, power in hands equal R. and L.	R. and L.	Vascular	Softening in anterior $\frac{4}{5}$ of L. first frontal and anterior $\frac{2}{5}$ second frontal gyri; corpus callosum destroyed on left side from genu to splenium	Cannot release an object that he had grasped. (Occasional)
Stauffenberg..	1918	L. arm	Very slight bilateral signs	L.	,,	Numerous areas of softening throughout the brain	Slow powerful persistent closure of hand on stroking palm
Parrisius ..	1921	L. arm	L. hemiparesis ..	None	Endothelioma	Growing from falx extending into frontal lobe, main compression on superior frontal gyrus, paracentral lobule, cingulum, anterior central convolution, and corpus callosum	The hand closed involuntarily when an object was placed within it against the patient's will. "Purely reflex"
Forster ..	1923	L. arm	L. hemiparesis ..	?	Glioma	Deep in R. frontal lobe	Could not open the hand for a time after he had grasped an object
Schuster ..	1923	R. arm	R. hemiparesis, very slight in arm	L.	Vascular	Softening L. first frontal gyrus from pole to central convolution. Corpus callosum and basal ganglia shrunken and scarred on left side	Forced grasping and groping
Riddoch and Brain	1923	R. arm	—	—	Tuberculoma	Immediately under cortex occupying whole of left frontal lobe and most of parietal and temporal lobes	Reflex closure of hand on stroking palm
Schuster and Pinéas, I	1925	R. arm	R. hemiparesis: severe in arm, less in leg. Can open and close hand voluntarily	L.	Vascular	Large softening in L. frontal lobe; corpus callosum thinned posteriorly; pons, caudate nucleus and putamen R. and L. contain small cysts. (Patient aged 65)	Forced grasping and groping
Schuster and Pinéas, II	1925	L. arm	L. hemiparesis, slight in arm, severe in leg	L.	,,	Softening of R. first frontal and cingular gyri and anterior part of corpus callosum; numerous lacunæ in basal ganglia R. and L. (Patient aged 78)	Do.
Schuster and Pinéas, III	1925	R. and L. arms	? None. Rigidity of upper limbs ("palli-därer Starre")	?	,,	Both frontal lobes atrophic, numerous lacunæ in basal ganglia. (Patient aged 60)	Do.
Schuster and Pinéas, IV	1925	R. arm	Slight R. hemiparesis	None	,,	Ditto. (Patient aged 77)	Do.

Authors	Date	Part affected	Pyramidal affection	Apraxia	Nature of lesion	Site of lesion	Remarks
Schuster and Pinéas, V	1925	R. arm	Very slight R. hemiparesis	None	Vascular	Recent hæmorrhage extending from R. frontal lobe to pons; cysts and lacunæ putamen R. and L.; hæmorrhage L. putamen destroying capsule. (Patient aged 63)	Forced grasping and groping
Schuster and Pinéas, VI	1925	R. arm	Severe L. hemiplegia	,,	,,	Softening of cortex of posterior part of left mid-frontal gyrus; also in right temporal lobe putamen, caudate nucleus and capsule	Do.
Stiefler ..	1923	R. arm	Slight weakness of R. shoulder, power in hands full and equal. Mayer's reflex normal L., greatly exaggerated R.	L.	Glioma	Extending forwards almost to the R. frontal pole and backwards almost to the dorsum of the genu	Forced grasping and groping; exaggeration of Mayer's reflex
Mayer, I ..	1923	R. arm	Slight weakness of lower R. face. No other pyramidal signs. Mayer's sign normal left, exaggerated R.	?	,,	L. frontal lobe	Do.
Mayer, II ..	1923	L. arm	Slight weakness of L. lower face. No other pyramidal signs, Mayer's reflex exaggerated R. and L.	?	,,	R. frontal lobe, extending to L.	Do.
Adie and Critchley	1927	L. arm	None at first, later L. hemiparesis	Bilateral	,,	R. frontal pole implicating the intra-frontal commissural fibres	Do.
Adie and Critchley	1927	R. arm	Very slight R. hemiparesis	None	Endothelioma	Attached to falx and impinging against the summit of the L. precentral gyrus	Forced grasping and groping
Adie and Critchley	1927	L. arm	Old left infantile hemiparesis	,,	Glioma	R. frontal pole, presenting at foot of first frontal convolution and extending downwards and forwards	Forced grasping and groping; exaggeration of Mayer's reflex

With moderate to severe degrees of paresis, the resting attitude of the hand is usually one of flexion; the patient is often found with the bedclothes or some other object clasped firmly in his hand, "as if this satisfied a grasping affinity" (Schuster). The appearance of a hand thus closed might suggest a severe contracture of pyramidal origin, were it not that the hand, when empty, can be opened actively and passively with ease. The hand sometimes closes reflexly if an object is placed within it during sleep.

Review of Cases from the Literature.

In searching for descriptions of cases similar to our own, we found many in which difficulty in relaxing the grasp occurred in patients who were not myotonic in the usual sense. Some of the cases were reported as examples of tonic perseveration or tonic innervation; in others the reflex nature of the symptom was recognized; in many the descriptions are so meagre that it is impossible to decide upon its nature. We give, in a table, an abstract of cases in which examinations of the brain were made after death, or the site and nature of a lesion were revealed at operation, and shall refer here only to cases and papers of special historical and clinical interest.

Liepmann [8] used the name tonic perseveration for the persistent contractions that sometimes occurred in his well-known patient, the Regierungsrat. At a stage when there was but slight weakness in the affected hand, and little or no apraxia, it was noticed that if he grasped an object he was unable to let it go; the hand remained closed in a powerful tonic cramp. At another stage, however, when he was unable to close the hand voluntarily, it closed at once upon an object placed within the hand. We shall have occasion to consider later the relation of tonic perseveration—a phenomenon that complicates voluntary muscular movements only—to involuntary grasping. It must suffice here if we say that in this classical case closure of the hand was certainly reflex at times, and that sometimes at least it occurred quite independently of volition.

Steinert [17] says of his patient, that when he caught hold of anything with the right hand he held it in a cramp-like grasp and had difficulty in releasing it again; if the observer gave the patient his hand it was difficult to free it from the embrace of his fingers. He speaks of this as "a kind of involuntary persistence of intentional closure of the hand"; his wording, however, does not rule out, but rather suggests, reflex closure. "It is difficult to release a hand that one has given

to the patient" (die Man dem Kranken gereicht hat); we are not told he was invited to grasp it firmly; his hand may well have closed involuntarily on that of the observer as soon as it came in contact with his palm.

In van Vleuten's case [19], "after he has grasped an object he is not able to terminate the innervation voluntarily; if he tries to let go the grasp becomes firmer; if he waits for some time, often two or three minutes, the condition passes off of itself." "He takes hold of an object correctly but holds it in a cramp-like grasp, so that the object cannot be removed by force though it is obvious that he is trying to let go." Here, again, cramp-like and very powerful closure of the hand occurred after he had "taken hold of an object *correctly*." We are not told the intentional part of the movement was powerful; the effect of placing an object within the palm was not tested, and although the defect was only noticed after he had taken an object in the hand himself, it is highly probable that the mere presence of an object in the palm caused reflex closure of the hand.

Another feature renders this almost certain, and shows that this case certainly belongs to our group, for we read that "if he puts an object down he grasps it again, embraces it closely, puts it down again and repeats this performance five or ten times, ending with the object still in his hand." This, so far as we know, is the first description of this particular manifestation of involuntary grasping. It was present in our third case and has been observed by others. The special signs were found in this case before any loss of power or alteration in the reflexes was detected; they disappeared with the onset of severe hemiplegia.

The first author to refer definitely to reflex closure of the hand was Janischewsky (1909) [5]. In a "complicated case with pseudo-bulbar symptoms," the patient could close the hand with great difficulty only, but the hand closed promptly and powerfully if the observer passed his hand gently across the base of the fingers. The patient was unable to relax the closure so elicited, and the observer had great difficulty in withdrawing his hand after it had been grasped. This case forms a landmark in the history of our subject, because the author states clearly that the closure of the hand "était certainement d'origine réflexe." Some years later (1914) the same author [6] reported a case, almost certainly one of frontal tumour, and gave the first full description of the "réflexe de la préhension." His paper contains an admirable clinical description, not only of the grasp reflex but of almost all the

accompanying phenomena. The brain of his patient was not examined after death, but the author suggested that the signs he had described "peut servir de signe révélateur d'une lesion localisée dans le lobe frontal au-dessus des centres sous-corticaux." Subsequent observations have confirmed his clinical findings, and one of our main objects here is to show that his surmise concerning the site of the lesion that produces the signs is correct.

In Reznicek's case [12] a vascular lesion produced a right hemiparesis, the leg being more affected than the arm. "After grasping an object in the right hand he could not relax his grasp. He always held the bedclothes in his fingers. Light stroking of the palm caused *reflex closure* of the hand."

In 1914, Wilson and Walshe [20] published a paper on "The Phenomenon of Tonic Innervation." In discussing their cases these authors confined their attention to the persistent closure of the hand that occurred after their patients had grasped an object voluntarily, and stated that this "was evident solely and exclusively during voluntary innervation of the muscles concerned." It is certain, however, that in two of their cases at least, and probably in all three, reflex closure of the hand was present, and it is clear from the text that some of the events they described had nothing whatever to do with purely voluntary innervation.

In their second case, "if the examiner attempted to withdraw his fingers rapidly from the patient's hand, the grasp of his fingers always tightened perceptibly." In the third case, "when the examiner put his fingers into her left hand her fingers at once closed on his, and she was unable to relax her grasp. The more she tried to release his fingers the more tightly hers closed around them." These clear descriptions leave no room for doubt about the nature of this particular symptom—the hand closed involuntarily in response to a stimulus to the palm—and we therefore include these cases as examples of involuntary grasping.

Parrisius [11] said that his case differed from others, in which difficulty in relaxing the grasp had been described, in that the closure of the hand in his case was "purely reflex." In 1923 Schuster [14] described three cases in which vascular lesions produced a very slight right hemiparesis, apraxia in the left arm, and involuntary grasping and groping in the right upper limb. "The almost absolute likeness in these three cases" he says, "makes it probable that we are dealing with a related complex of symptoms—a syndrome."

In an excellent clinical description he confirmed the findings of Janischewsky, van Vleuten and Rezniček, and described for the first time the "butting in" phenomenon that was present in our third case. He observed, too, that if he brought an object close to the palm and told the patient to grasp it as soon as it touched the palm, this was done at the right moment on the normal side, but always prematurely on the affected side.

In 1925, Schuster and Pinéas [15] described a number of fresh cases, in six of which a post-mortem examination was obtained, and formulated conclusions concerning the site of the lesions that are responsible for involuntary grasping and groping. Finally, Stiefler [18] described a case of his own, and gave an account of two of Mayer's, in which a tumour in one frontal lobe gave rise to very definite reflex grasping and groping in the opposite upper limb. The reader is referred to the table for further information about these cases.

Nomenclature.

Closer consideration of the signs we have just described shows that we are dealing with phenomena that increase in complexity from purely neurological to more psychological reactions. So far we have used the terms involuntary grasping and groping to cover them all. We have considered various names for the use of those who employ the English tongue, but have been unable to find any that are equally comprehensive.

Janischewsky spoke of the *réflex saississeur* and later of the *réflex de la préhension*; similarly, Parissius proposed the name of *Greif reflex*. The name "grasp, or grasping reflex," is short and convenient, but it does not comprehend the phenomena that almost invariably accompany reflex closure of the hand, and, unfortunately, it may mean more than one thing. If we read that the grasp reflex is present, we do not know the exact nature of the response; it may mean that the fingers adopted a grasping attitude (crab's claw reflex), or the hand closed upon the object but could be opened at once (incomplete grasp reflex), or that closure was followed by a persistent contraction which revealed itself when the patient attempted to open the hand voluntarily, or when efforts were made to withdraw the object forcibly from the palm (complete grasp reflex).

Schuster uses the term, *Zwangsgreifen im engeren Sinne* (involuntary or forced grasping in the narrower sense), for the incomplete grasp reflex.

If a special name is required for the repeated gentle grasping movements that sometimes occur after an object has been forcibly withdrawn, we suggest "after grasping" by analogy with after discharge.

Some special terms are certainly necessary to designate some of the more complex movements that usually accompany the grasp reflex. We have seen that the hand, the arm, and even the body, may turn and move in the direction of a stimulus, and that the limb may be drawn in any direction by repeating the stimulus (magnet sign). The appearance in the latter instance is very striking; the hand moves promptly in the direction of the stimulus, making a tentative grasping movement as it goes, and the picture is exactly that of a person groping for an object with his eyes closed.

To indicate this added feature of direction, Schuster uses the term, "*Nachgreifen*" (towards grasping). We think "forced groping" expresses the desired idea.

We are left with phenomena on a still higher plane, in which the hand moves towards and grasps objects, not in response to a stimulus applied to it immediately but upon the mere approach or proximity of an object. We have an example of this in the premature grasping that occurs when an object is brought close to the palm. This, and the obtrusion of the affected hand upon the actions of the healthy one, might be called "impulsive grasping"; and the regrasping that foils the patient in his effort to rid his hand of an object, "impulsive regrasping."

This indication of the increasing complexity of the movements that may be observed in our patients would be incomplete without mention of phenomena that were not present in our own patients, but were observed by Schuster in strictly comparable cases. In our cases the movements occurred without the patient's knowledge, they were involuntary, no more than pseudo-spontaneous. The patient was often annoyed by the movements, especially when the affected hand obtruded itself persistently and undid the work of the good hand, but he experienced no conscious sense of satisfaction or relief when the hand had succeeded in grasping an object. Schuster, however, tells us of patients who were conscious of an urge to grasp objects, and experienced a sense of relief when they had done so.

Site of Lesion producing Forced Grasping and Groping.

We have seen that Janischewsky attributed the symptoms in his earlier cases to a subcortical lesion in the frontal lobe. In a recent

paper, however, he modified this view; he seems to believe that a lesion confined to the basal ganglia can produce them, and he now states rather vaguely that the lesion is in "the upper parts of the extrapyramidal motor system."

Schuster, too, first placed the lesion "in the subcortical white matter, not too far from the anterior central convolution"; later he found "changes in the basal ganglia in the majority of his cases." He himself said that his findings should be accepted with reserve, but this has not prevented later writers from using them as evidence in support of the contention that the symptoms can be produced by lesions confined to these parts.

We have taken pains to acquaint ourselves with the pathological findings in all cases of reflex grasping and groping where the brain was examined after death, without finding a single case in which lesions were *confined* to the basal ganglia. Nor were we impressed with the cases in which changes were found there; the patients were all old, some very old, and the changes—lacunæ, cysts, areas of softening, and the like—were those that are found in many old people who present no motor disturbances during life. In every case areas of softening and other degenerative changes were found in the frontal lobes also.

We approached the study of Kleist's cases [7] with some interest, as this writer is responsible for a much quoted theory of the pathogenesis of these symptoms and of "psychomotor hyperkineses" in general. He attributes them to a lesion of afferents to the corpus striatum by way of the superior cerebellar peduncle and thalamus, or of the corpus striatum itself. But the cases on which he bases his conclusions are by no means convincing.

In one, a patient aged 76, with forced grasping and automatic closure of the hand on stroking the palm, cysts, lacunæ and areas of softening were found throughout the basal ganglia; but the brain as a whole was small, especially the frontal lobes, and contained many small foci of softening.

In another, with forced grasping in response to tactile and optical stimuli, a large glioma occupied the white matter of the lower and posterior part of one frontal lobe and extended to the lower part of the parietal lobe. In Noethe's case, which he quotes as an example of unilateral hyperkinesia due to disease in the corpus striatum, the globus pallidus was destroyed, but the softened area included part of the frontal lobe and the central convolutions.

It would be tedious to multiply examples. The writers who explain

so much by invoking the aid of the basal ganglia, seem to place the microscope to their blind eye when they view other parts of the brain. We repeat that we have discovered no case in which reflex grasping and groping occurred in lesions confined to these parts. On the other hand, we have discovered no case in which the frontal lobes were healthy, but several in which the lesions were certainly confined to this lobe and in which the basal ganglia were intact.

We conclude, therefore, that forced grasping and groping are expressions of disease in the frontal lobe. The nature of the cases at our disposal renders more definite localization difficult, but we are inclined to think that the lesion responsible for these symptoms is in the upper and posterior part of the frontal lobes. This is suggested by the site of the lesion in a number of cases (Wilson and Walshe, Goldstein [4], our cases 2 and 3), and is perhaps supported by the fact that in a great many of the cases the leg was definitely weaker than the arm.

Relation to Delay or Difficulty in relaxing the Grasp in other Conditions.

One of the most obvious of the phenomena that we have described, namely, difficulty in relaxing the grasp, occurs in a number of dissimilar disorders. It is familiar as a manifestation of true myotonia in dystrophia myotonica and Thomsen's disease. The appearance of the hand as the patient tries to relax his grasp is exactly the same in true myotonia and in our cases, but confusion is hardly possible if all the features are considered.

Difficulty in relaxing the grasp has frequently been described in patients with athetosis, or presenting other syndromes held to be due to diseases of the basal ganglia. Delay in opening the hand is characteristic of spastic paralysis of the arm at a certain stage of recovery, and is therefore frequent in ordinary hemiplegia, and considerable delay is sometimes seen in patients with cerebellar disease; but our cases differ fundamentally from all of these in that persistent closure of the hand occurs, not only after voluntary innervation but also after the hand has closed reflexly in response to sensory stimuli applied to it.

Several cases of involuntary grasping with persistent after-contraction have been published as examples of tonic perseveration or tonic innervation. By definition tonic perseveration (tonic innervation) is a condition in which innervation of a group of muscles persists unduly after it has been initiated voluntarily; voluntary efforts to inhibit the

contraction serve only to increase it; it is evident "solely and exclusively during voluntary innervation of the muscular groups concerned" (Wilson and Walshe).

But the authors who placed their cases in this category were unaware of the existence of involuntary grasping; they noticed persistent contractions after voluntary closure of the hand, but did not apply tests to see if the hand closed reflexly; some of them, however, give particulars which prove that reflex grasping was certainly present in the very cases on which they base their conclusion that tonic innervation complicates voluntary contraction only.

It is perhaps significant that no case of tonic perseveration, as defined above, has been described in recent years, whereas cases of persistent contraction associated with reflex closure appear to be common. We have seen five cases in the course of a few months, and Schuster refers to about twenty that have come under his own observation since 1923.

Nevertheless, we are convinced that the same persistent contractions as those seen after reflex closure may occur after voluntary contractions only. We have had a patient under weekly observation for the last six months who has presented the phenomena of tonic perseveration consistently, but has never shown the slightest sign of reflex grasping or groping. Although tests for reflex grasping were not performed in Wilson and Walshe's cases, we think that their first case was of this kind; we are inclined to include Liepmann's case (at one stage) and Steinert's case in the same category.

Is there any essential difference between the persistent contractions in the two groups? Does tonic perseveration occur after voluntary contractions only (Liepmann, Wilson and Walshe), or is it merely the final event (*Schlussakt*) in reflex grasping (Schuster)? We believe that neither of these extreme views is the correct one, but that exactly the same phenomenon may follow voluntary or reflex closure of the hand.

It has been unduly emphasized, as if it pointed to some difference, that patients with reflex closure have no difficulty in opening and closing the empty fist at will, whereas persistent contractions occur in tonic innervation after closure of the empty fist. Our experience has been that patients with reflex closure are sometimes unable to open the empty fist; in one of our patients on whom we made appropriate tests, persistent contractions occasionally followed firm voluntary closure of the hand. Schuster mentions this in the description of one at least of his cases. Further, patients with persistent contractions after voluntary

closure of the hand are also able to open and close the fist at will so long as the movements are gentle. To evoke the phenomenon of tonic perseveration, firm persistent voluntary closure is usually necessary.

The differences, we think, are due to lack of complete examination; those who have studied reflex grasping and groping have noticed that gentle, repeated opening and closing of the empty hand is possible, but they have not tested the effect of powerful, prolonged voluntary closure of the empty hand; further, they have confined their attention to muscles that close the hand; on the other hand, those who have studied tonic perseveration, while describing the after-effects of firm voluntary closure of the hand, have not tested for reflex closure, but have found persistent contractions in other muscles on the affected side. In future, no doubt, appropriate tests will be applied for detecting all these defects when one of them has been discovered.

Our own case (H. C.) shows that tonic innervation and reflex grasping and groping may be present in the same patient at different times. In this case persistent contractions also occurred in muscles moving the elbow-joint. In van Vleuten's case tonic perseveration in the muscles of the arm and leg on the affected side was associated with typical forced grasping.

The only point of difference, so far as we can see, between persistent contractions after voluntary and reflex closure—conditions that have hitherto been described separately—is the ease with which the latter can be elicited. In these the mere presence of an object in the hand may suffice; in those firm and prolonged voluntary closure of the hand is necessary. But the difference, we think, is qualitative only; in one case the trigger, as it were, needs a harder pull to release it than in the other.

In Wilson and Walshe's cases of tonic innervation the tumour was an endothelioma; in one the tumour was entirely superficial, in the other it was found a quarter of an inch below the surface of the brain. A tumour of this kind produces its effect mainly by pressure; in the cases with grasping in response to tactile stimuli, the lesion was either a glioma or softening from vascular disease—conditions in which more destruction of nervous tissue is likely to occur.

Further observations will perhaps confirm our surmise that a lesion that produces reflex grasping with persistent contractions is always more extensive and more destructive than one that produces persistent contractions after voluntary innervation alone. We have seen tonic innervation follow a vascular lesion, but if, in a particular case with

tonic innervation without reflex grasping, the accompanying signs indicated the presence of a cerebral tumour, we should be inclined to diagnose endothelioma rather than glioma. Be this as it may, our opinion with regard to the relation of tonic innervation to reflex grasping is that the persistent contractions in both are one and the same phenomenon.

Nature of Forced Grasping and Groping.

In the patients who present the signs that we have described there are no psychical disorders; their memory is good; they are attentive and understand perfectly what is required of them; sensation in all forms is intact; the signs are found in many cases before any evidence of weakness or altered tone can be detected; in many there is no trace of apraxia. The movements in the flexors and extensors of the forearm and hand are co-ordinated perfectly so long as the movements are gentle and the hand is empty; yet certain movements of the hand cannot be prevented, and once the hand has closed reflexly upon an object, or has been closed voluntarily and firmly, it cannot be opened. The will to open it is there; the extensors are innervated powerfully but the flexors fail to relax. Relaxation is delayed, and the grip tightens when attempts are made to remove an object from the hand passively and when the patient makes voluntary efforts to relax; partial or complete relaxation occurs when voluntary innervation ceases, and when the palm is no longer stimulated.

Some have thought that forced grasping and groping are manifestations of apraxia. They are often found together, but one may be present without the other and, with unilateral apraxia, forced grasping may be confined to the eupraxic or dyspraxic limb. It is certain, too, that lesions of the corpus callosum, though common, are not essential. We agree, therefore, with Schuster's later view that forced grasping and groping are not manifestations of apraxia in the accepted sense.

A consideration of the stages in the development of grasping in normal infants gives a clue to the manner in which this function might be expected to disintegrate in disease, and provides us with examples of imperfect grasping analogous with those that concern us here.

During the first few months of life the hand of an infant clasps an object placed within it firmly and persistently; by a finger in its grasp its arm and sometimes its whole body can be raised. Some anencephalic monsters show the same reflex grasping.

Late in the second or during the third month, the infant begins

to grope for objects; at first the hand closes on the object only if it is placed within it, or finds its way there accidentally, but after the fourth or fifth month the grasping movement begins to have the appearance of what we call a voluntary action. The closure, however, is still persistent, and the hand clasps the object firmly as long as it remains within it. Then by degrees the hands become more adroit; the power of relaxing the grasp begins to develop, and an object held at a height can be released with the aid of gravity so that it falls to the ground.

Towards the end of the first year, when he has reached the stage of crawling, he passes from one object to another, picking up now this and now that, as a new object catches his eye. On his way from one to another he drags the last object with him, and it leaves his hand more by accident than by intention; later the object falls from his hand as soon as his attention is diverted.

The time then arrives, about the end of the first year, when he will empty a box by turning it over and then attempt to replace objects within it. He lifts them up very neatly; his movements are well co-ordinated; his intention is obvious; but as often as not, after placing the object in the box, when he withdraws his hand the object is still within it and he has to try again.

While he *tries* to rid his hand of the object he is unable to do so, but if his attention is diverted by a call, or if he tires of his game, the object drops from his grasp at once. Very soon after this all difficulty in relaxing the grasp disappears and his skill in handling objects increases apace.

The new-born infant, then, first shows reflex and persistent grasping. Later it begins to grope and reach out for objects, but still closes the hand only in response to the contact of an object. Then it learns to pick up objects and transport them at will, but is still unable to relax the hand, and finally both closing and opening movements of the hand are performed with ease.

We resist the temptation to describe these interesting events in greater detail, but must emphasize the fact that, just as in persistent grasping of adults with disease, so at a stage in normal infancy relaxation of the hand is hindered by voluntary efforts to effect it. A mother said of her son, aged 11 months: "He emptied a box of cotton reels and was trying to put them back one by one; sometimes he succeeded, but more often the reel came out in his hand again; once he had made an unsuccessful attempt and was withdrawing his hand containing a reel when his sister called him; he looked up, his hand opened at once,

and the reel dropped into the box." We have confirmed this observation, and have noted the same thing in other children of about the same age.

The power to open the hand at will, then, after it has closed upon an object, is acquired late. Last to come—first to go; difficulty in relaxing the grasp after voluntary closure of the hand, a difficulty increased by conscious efforts to overcome it, is an expression of disintegration in the grasping mechanism that might be expected from a lesion affecting its highest components. Thus, perhaps, tonic innervation can occur with cortical lesions, or with more superficial and less destructive lesions than those that cause reflex grasping and groping, these being due to more profound disintegration of the same mechanism.

In infancy complicated nervous reactions occur at a time when there is little or no myelinization in the neo-encephalon, say before the fifth month; gradually, however, the automatic and immediate reactions of early infancy are modified, and mediate, less automatic reactions appear, presumably *pari passu* with the development of the newer parts of the brain. The structures concerned in the earlier reactions come under the control of a mechanism on a higher physiological level. If this control is removed, we may expect a reappearance of reactions analogous with those of an earlier stage of development. (For reasons into which we shall not enter, they are not necessarily identical.)

This, we believe, is what happens in patients with forced grasping and groping: motor centres capable of independent activity are deprived of controlling influences from higher centres, and signs appear which are expressions of the less controlled, more primitive, more immediate, more automatic activity of lower centres. We must now attempt to decide whence this control comes and where it is exercised.

The prevailing view (Foerster, [2] Kleist, Schuster, Pinéas) is that the symptoms can be produced by lesions confined to the basal ganglia, and that they are due to loss of control usually exercised by or through these structures. Thus, Kleist writes of "de-inhibition (*Enthemmung*) in the realm of striate automatisms," and attributes reflex grasping and other "psychomotor hyperkineses" to lesions of the corpus striatum itself, or of afferents that reach it by way of the superior cerebellar peduncle and thalamus.

According to those who weave romances in the realm of striate automatisms, a region we enter unwillingly, the caudate nucleus with the putamen (together referred to as the neostriatum or striatum) belongs

to the neo-encephalon; myelinization occurs late here—after the fifth month—but is present at birth in the paleo-encephalic globus pallidus (pallidum) and thalamus. During the first few months of life the child is a "thalamo-pallidal being" (Foerster). Impressions from the periphery reach the thalamus and pass to the pallidum, whence regulating impulses pass to motor centres in the brain-stem; this is the period of automatic reactions. Later, as myelinization takes place in the striatum and cortex, the automatic reactions become modified and more complicated, less automatic, reactions occur. When the striatum is diseased, the pallidum—now isolated from higher controlling centres, but still receiving impressions through the thalamus—becomes hyperexcitable and hyperactive, and performs its functions in an abnormal manner; hence the psychomotor hyperkinesis.

This conception of the part played by the basal ganglia in the integration of the nervous system and in the production of disorders of muscular activity has the virtue of simplicity, but unfortunately it is based on pure surmise and receives no support from the evidence supplied by experiment or disease. The researches of Magnus and de Kleijn have given us an insight into the complexity and functional perfection of automatic reactions in mid-brain animals, reactions that are not materially influenced by the presence or absence of the thalamus. Already it is clear that some of their results in animals may not be applied in detail to man, but in principle they are unassailed and unassailable; we cannot believe that an organ which is unessential for the regulation of a great group of automatic muscular activities in mid-brain animals is of supreme importance in the regulation of general automatic activity in the human infant.

Moreover, as we have seen, no case of forced grasping and groping has yet been described in which lesions were confined to the basal ganglia. For these reasons we do not believe either that the symptoms are due to the loss of a controlling influence on spinal centres that is normally exerted by or through these structures, or that they are expressions of their uncontrolled activity. But lesions in the frontal lobe were present in every case, and in some all other parts of the brain were healthy; we must conclude, then, that the source of the control that is lacking is the frontal cortex.

If this control is not exerted through the basal ganglia, what is the path of the regulating impulses? Stiefler [18] attributes the symptoms to loss of inhibitory impulses that normally reach spinal centres by a fronto-rubrospinal path. His chief concern was to explain the exaggera-

tion of Mayer's reflex; in two of his cases of frontal tumour this sign was associated with forced grasping and groping in the same hand. We found this combination in two of our cases; in every case so far described, of exaggeration of Mayer's reflex in patients with a cerebral tumour, forced grasping and groping were present as well; we think, therefore, that this combination of signs is important, and conclude firstly, that they are expressions of disturbance in the same or closely related anatomical structures, and secondly, that the mechanism of their production is the same.

Now our own experience leads us to agree entirely with Mayer and Stiefler in their view, which has been attacked by others, that the integrity of pyramidal fibres for the muscles of the hand is essential for exaggeration of Mayer's reflex. In all the cases of cerebral tumour in which it has been observed, i.e., in two of Mayer's, one of Stiefler's, and two of our own, signs of pyramidal disease were entirely absent or, with paresis in other parts, the hand was entirely spared; as soon as weakness appeared in the hand, not only exaggeration but the normal reflex itself disappeared.

We are able to confirm another observation of Mayer's; in several cases of cerebral tumour that have come under our observation loss of his reflex heralded an oncoming hemiparesis and served as a localizing sign at a time when other signs of pyramidal disease were still entirely absent. Up to a point the same applies to forced grasping and groping; these signs are seen at their best when pyramidal signs are absent; some of them disappear with the first sign of weakness in the hand, and all of them disappear when the hand becomes completely paralysed. It is likely, then, that the lesion responsible not only for exaggeration of Mayer's reflex, but for forced grasping and groping as well, is extrapyramidal.

It is certain that a rubrospinal tract conveys impulses concerned in the regulation of tone in voluntary muscles, but our symptoms are found in limbs with normal tone; if they are due to interruption of a fronto-rubrospinal path, they should have been found many times ere now with lesions of the brain-stem; Stiefler examined serial sections of the brain-stem in one of his cases, but found no degeneration in any descending tract. We feel, therefore, that his suggestion must be unsatisfactory while our knowledge of the course and function of extra-pyramidal efferents from the frontal cortex remains in its present imperfect state.

The foregoing considerations have forced us to the conclusion that

reflex grasping and groping, and the exaggeration of Mayer's reflex, are expressions of disturbance in a constellation of cortical mechanisms whose influence upon spinal centres is exerted through the pyramidal tract as a final common path; the lesion is extrapyramidal only in the sense that it is prepyramidal. The signs may be expected when these cortical areas or their subcortical connections are damaged.

We do not think any apology is required for the expression "constellation of mechanisms." A function so important as grasping must be subserved by a large area of the cortex; within this area there must be anatomical arrangements which permit infinite combinations and permutations in the impulses that finally impinge on pyramidal cells whose fibres pass to the muscles of the hand and arm.

In our patients, after the hand has closed voluntarily or in response to a sensory stimulus, it cannot be opened again if voluntary efforts are made to open it, or if efforts are made to withdraw an object forcibly from it; in the one case stimuli of cortical origin are passing through the centres concerned in grasping; in the other stimuli are pouring in from the palm; in both, stimuli are reaching the cortex from the contracting flexors.

If certain parts of the cortex or their subcortical connections are damaged, the whole mechanism of grasping will be disturbed in various ways, because many paths formerly open to incoming impulses will now be closed and their distribution will be abnormal; further, distorted responses to these stimuli may be expected, because the normal effector paths from the centre to the cells of origin of the pyramidal tracts are also interrupted.

The symptoms in our cases cannot rightly be attributed to a progressive disintegration of one centre, or gradual increasing destruction of one tract, because they do not appear in any definite order; some of them are present in one case, some in another, and no two cases are exactly alike or run the same course, although the lesions are roughly in the same part of the brain. We can understand these differences if we attribute them to varying degrees of damage to a number of structures closely related anatomically.

If the symptoms depend upon a lesion of cortical structures or subcortical connections between them, then the nature of the disturbance is certainly one in which there is some defect in inhibitory processes, for it is by the mysterious process we call inhibition that cortical activity alters spinal and decerebrate reflexes when necessary, and renders possible the minute and endless adjustments of the organism to its surroundings.

We have seen that defects strictly analogous with those in our patients are met with in infants who are learning to use their hands. According to our view, the movements during this learning process become less automatic and more controlled as reflexes are acquired conditionally which supplant the unconditioned reflexes dependent on reflex paths present at birth. We know, from the work of Pavlov, that the anatomical basis for acquired (conditioned) reflexes is in the cerebral cortex; when the part of the cortex containing the anatomical paths concerned in the conditioned reflexes associated with the function of grasping is damaged, more primitive, less controlled reactions in the shape of forced grasping and groping reappear.

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SUBCORTICAL EPILEPSY.[1]

BY WILLIAM G. SPILLER, M.D.

Professor of Neurology in the University of Pennsylvania.

RECENT investigations (Richter, Foerster, Wilder) indicate that the immediate cause, what the French call the *agent provocateur*, not necessarily the predisposing cause, of the epileptic convulsion, is angiospasm of the brain. Foerster says he has seen angiospasm of the exposed brain on the operating table immediately precede the convulsion more than a hundred times.

It is not, however, the epileptic convulsion in general which interests me at the present time, but one of the forms of the convulsive attack.

A condition in which brief epileptic motor attacks occur, consisting entirely or chiefly of tonic spasms, has been recognized, but it is a difficult problem to select that name for these attacks which is most descriptive and at the same time accurate in the interpretation it suggests. The term "spastic epilepsy" offered by Knapp is not satisfactory. "Extrapyramidal epilepsy," employed by Sterling, at first thought seems to cover the ground, but it implies that the pyramidal tract has no part in these paroxysmal spastic conditions. While they may be regarded as chiefly extrapyramidal in origin, it does not appear possible, in the light of our present knowledge, to exclude the pyramidal system from all participation in them. Wimmer's term of "striate epilepsy" is a striking one, but it is open to similar objection, and it does not seem advisable to me to exclude other structures near or below the corpus striatum from having a part in these attacks. Although I am not aware that the term subcortical epilepsy has been employed for this peculiar condition, it seems to me the most suitable.

Within the past few months two cases have been under my observation in which prominent symptoms were brief tonic spasms of both hands and one lower limb in one case, and of one upper and one lower limb on the same side in the other. It happens that in these two cases the tonic spasms affected only one lower limb, but I do not believe

[1] Presidential address read before the Philadelphia Neurological Society, January 28, 1927.

that in all similar cases only one lower limb will be implicated. These tonic spasms, without any clonic element, were brought on by voluntary movement of the affected limbs in both cases, but in one case could be produced by passive movement. In both cases the tonic spasms were associated with paræsthesia predominantly of a hot or burning character in the lower limb unaffected by spasm, developing simultaneously, and disappearing simultaneously with the tonic spasms of the other lower limb. It may be that this paræsthesia was really bilateral, but was masked in the tonic limbs by the intensity of the pain produced by the contractions.

Case 1.—A woman, aged 62, was referred to me by Dr. H. G. Rudner, of Memphis, Tenn., November 1, 1926. She had been blind in the left eye for eight years, since July, 1918, and the sight in the right eye had begun to fail five years previously, on account of optic atrophy, so that her disease had been present at least eight years, although there seemed to have been a great increase in the symptoms during the previous six months. In June, 1926, paræsthesia developed in the hands, about the same time she had a sense of constriction about the waist; spasms began in the hands the latter part of September, and they were felt in the right lower limb about the same time. These spasms, distinctly tonic in the right lower limb, were brought on by voluntary movement. When she had a "cramp" in the right lower limb she had simultaneously a sensation of warmth extending down the left lower limb as far as the instep. These spasms lasted a few seconds or half a minute. They had become more frequent since their onset. At the same time she had a sensation of spasms in both hands, which she described as "a contraction of the muscles without any pain." The right lower limb was very spastic only during a spasm. When she first entered the hospital she complained of the spasms in both hands and the right lower limb each time she attempted to move after a period of rest, especially to walk or stand. The muscles of the right calf were in strong contraction during a spasm. While she described the spasms as without pain they were very uncomfortable. The attacks in the hands were different from those in the right lower limb. Almost any movement of the neck or trunk produced an uncomfortable drawing electric sensation, more pronounced in the left upper extremity, beginning at the elbow and extending into the fingers, and lasting about thirty seconds, and with athetoid movements of the fingers which seemed to be an attempt on the part of the patient to overcome the disagreeable sensation. The right forearm and hand were affected less often, but the patient said the attacks were more severe in the right hand when they occurred there. The spasticity of the hands and forearms during an attack was not very pronounced.

In walking she moved her right lower limb awkwardly, as though it were weak, and with a tendency to scrape the toes along the floor. Both patellar reflexes were exaggerated and equally. The Achilles reflex was very prompt

on each side, and after a spasm an abortive ankle clonus was obtained on the right side, but not on the left side. Vibratory sensation was lost in both lower limbs and in the pelvis on both sides, but was normal in the hands and upper limbs. The sense of position was fairly acute everywhere. The motor power of all the limbs was usually normal. Taste and smell were possibly less acute on the left side.

Dr. Pancoast found by X-rays: Very much exaggerated venous channels extending down to the fronto-temporal region on each side, more on the right. The pituitary fossa was slightly enlarged on one side. The whole skull was considerably thickened, not twice the normal thickness, and the thickening was very pronounced over the base of the skull from the frontal region to the foramen magnum.

The thoracic spine showed hypertrophic spondylitis most marked in the lower portion, the same condition was very pronounced in the lumbar region.

It was evident that the bone thickening had been developing for several years. It is possible that the membranes at the base of the skull shared in the thickening, and these lesions were very near the optic chiasm and optic nerves. The laboratory findings did not support a diagnosis of syphilis. It was possible that a basal tumour was present, but it was evident that some irritation at the base of the brain must be present.

Case 2.—Mrs. Anna R., aged 46, entered the University Hospital, October 1, 1926, under the care of Dr. F. C. Grant, and the photographs were taken under his direction. I have made use of the notes taken by Dr. Appel and Dr. Alpers, as well as of those taken by myself.

The patient was well until August, 1926. Eight weeks before she entered the hospital she had pain in the right side of her head and neck, and "noises" in her head. She had nausea and vomiting frequently for several days, which then ceased. About the same time as the onset of the symptoms, she noticed weakness in her right lower limb and had difficulty in walking. This weakness increased, and gradually the right upper limb and right side of her face became weak. Her vision began to fail with the onset of the other symptoms, and the vision was worse in the right eye. She had been bedridden four weeks when she came to the University Hospital, and her memory had been failing for some time. Consciousness was not lost at any time. While the right hemiplegia was of gradual development, the onset of the paralysis was with nausea and vomiting for several days, but not later.

On entrance to the hospital she was found to have hypæsthesia for touch and pain sensations in her right upper and lower limbs and trunk, but not in her face. Temperature sensation was not affected. She had a flaccid paralysis of the right limbs, and could not raise either right limb from the bed, could barely flex the right fingers, but could extend the forearm on the arm. Her mental condition was somewhat impaired. She was very restless. Dynamometer in the right hand registered 0; in the left hand 30. Her biceps, triceps, patellar and Achilles reflexes were diminished on the right side. Her neck was stiff.

Some return of motor power only in the right lower limb was observed on October 10, and marked return of motor power in the right upper limb on October 13. She was then able to carry her hand to her nose and to move her right fingers. The right lower limb had also gained increased power. Carpopedal spasms, as in tetany, were first noticed on October 23, and they occurred at irregular intervals. The attacks appeared to be brought on by changing the position of the body, but they occurred also while the patient

FIG. 1.—Showing the spasm of the right upper limb, with flexion of the fingers and elbow.

was at rest. They lasted about a minute, and during the spasm the patient felt a sense of constriction in the right upper limb and shoulder. The spasms continued, and gradually increased in severity and caused her great distress. When she entered the hospital it was noticed that the right pupil and the right palpebral fissure were smaller than those on the left side, and there was enophthalmos of the right eye.

By October 18 she was able to flex, extend and abduct her right upper limb. The dynamometer now registered in the right hand 25; in the left 40.

She was able also to flex and extend her right lower limb, but the improvement here was not as great as in the right upper limb. The tendon reflexes of the right upper and lower limbs were still diminished. The sense of position was markedly impaired in the right thumb, index and middle fingers, but was intact in the ring and little fingers, and astereognosis was complete in the right hand. She complained of a drawing or tight feeling at times in

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FIG. 2.—Showing the smaller palpebral fissure on the right side as a part of the paralysis of the ocular sympathetic fibres.

her right upper limb, with a sensation of hot flashes on the entire left side of her body. Tactile sensation was diminished over the right upper and lower limbs, but temperature sensation was recorded as normal.

By November 1 the tonic spasms had become very frequent, the right upper and lower limbs became spastic, and the right hand was in carpal spasm. The tonic spasms usually were first observed in the right upper limb, the whole limb being involved at one time; a sensation of numbness preceded

the spasm, and the attacks were more frequent when the patient was emotionally disturbed. They lasted about five or ten seconds, and were very painful. The reflexes on the right side were increased during the spasms, but no Babinski reflex was obtained at any time at this date.

The blood and spinal fluid Wassermann were negative. The spinal fluid taken on October 1 showed 70 white and 1,200 red blood-cells to the cubic millimetre. A puncture made on October 5 yielded a fluid containing 42 white and 740 red cells, and by October 25 the fluid contained 11 white and 2 red cells.

An ocular report by Dr. A. C. Fewell, October 1, was: Ocular rotations full, pupils unequal, O.D. 3 mm., O.S. 5 mm. The right pupil did not react to light, the left was active. The media were clear, the discs were rather grey on the temporal side, deeper layer, superficial capillarity good, margins well defined, no discrete changes. This condition would not be regarded as an atrophy unless vision were down and fields contracted.

On October 21, Dr. Fewell's report was: Vision of the right eye was $\frac{1}{60}$; of the left $\frac{6}{12}$. No colour was recognized in the right eye. Left eye more prominent than the right. Ocular rotations full. Pupils unequal, the right $4\frac{1}{2}$ mm., the left 6 mm. in subdued light. Both reacted to light, but left more promptly. The right palpebral fissure measured 13 mm., the left 14 mm. The media of the right eye were clear. The disc was grey, especially in the temporal side. The vessels were normal. No changes in choroid or retina were observed. The left media were clear, the disc was better in colour than in the right eye, but somewhat grey. The vessels and general fundus were healthy. Four per cent. cocaine was instilled in each eye; thirty minutes later the right pupil measured 5 mm., and the left $7\frac{1}{2}$ mm. Exophthalmometer, right, 11; left, $13\frac{1}{2}$. The fields were not definitely contracted.

I visited this patient several times. Her tonic spasms were caused by any manipulation of the right upper limb; she dreaded to have this limb handled because of the pain produced by the spasms, and she begged not to have the limb moved. The fingers of the right hand in spasms were flexed partly at the metacarpo-phalangeal articulations, and the thumb flexed into the palm. A spasm was not accurately timed, but seemed to last about a minute or two. Consciousness was not affected during an attack.

The right lower limb usually became spastic in extension during a spasm of the upper limb.

I saw this patient on November 21, and she died in the night of this day; a necropsy could not be obtained. She appeared very ill, the right hand was in permanent tonic spasm, and was flexed into a fist with the thumb projecting through the fingers. She could not at this time open the hand voluntarily. The right lower limb was not in spasm, and passive movement of the right upper limb did not cause spasm of the right lower limb as it had done at former examinations. Passive movement of the right lower limb did not cause spasm of this limb.

The spasms were observed by many persons during the patient's stay in

the hospital. Dr. Kubitschek described them as he saw them on November 6. Her expression was one of anxiety and suffering. Within a minute a spasm occurred causing a severe tonic contraction of the right hand, fore-arm and arm. These parts were extremely rigid. The right lower limb was equally rigid in extension; the left fore-arm and hand were moderately spastic, and the fingers showed athetoid movements; the left lower limb was slightly spastic. She complained of severe pain across the head and the nurse relieved this by

FIG. 3.—Showing the paralysis of the ocular sympathetic fibres on the right side.

pressure in the temporal regions; of intense tightening sensation in the right upper and lower limbs, and of severe burning sensation in the left upper and lower limbs. The spasm lasted between half to one minute, and was followed by flaccidity in all four limbs.

The nurse stated that these spasms occurred about every three or four minutes throughout the day, and were only partly relieved by morphine or codeine. They formerly occurred only on motion, but they had increased in frequency, especially during the previous week, and occurred even when the

patient was at rest. During the previous week she had been having two or three attacks each night.

Dr. Alpers described the attacks as seen by him, November 6: "If she became excited she had attacks in rapid succession. Movement of the upper or lower limb induced these spasms, while absolute quiet reduced their frequency. Of late the attacks had been getting so severe as to make the patient cry out in pain. A typical attack began in the right fore-arm and hand with no definite localization, and started with a stiffness of these parts, which in a few seconds reached a maximum and caused the patient to cry out. The right fore-arm became flexed on the arm, and the hand was held in carpal spasm, with the thumb between the four fingers. The arm, fore-arm and fingers were extremely rigid in these attacks. The right lower limb also was rigid, but not so much so as the upper limb, and was held extended. The spasm lasted about thirty seconds and disappeared suddenly. At first opening the fingers of the right hand gave relief, but this had become of no avail. Recently her hand had become stiff during the attacks. Simultaneously with these spells she had a hot flush which passed down her left side, and which gave her great discomfort."

The above description by Dr. Alpers corresponded accurately with my observations. I had asked for a report by Dr. Fewell regarding the effect of cocaine on each eye, and as mentioned his statement was: "Four per cent. cocaine was placed in each eye. Measurement taken in thirty minutes, right pupil 5 mm., left pupil $7\frac{1}{2}$ mm. Exophthalmometer, right eye, 11: left eye, $13\frac{1}{2}$. The pupils before the application of cocaine measured, right, $4\frac{1}{2}$ mm., left, 6 mm. It will thus be seen that under cocaine the right pupil dilated $\frac{1}{2}$ mm., the left $1\frac{1}{2}$ mm. The right pupil was, therefore, less responsive to the stimulation by cocaine of the sympathetic fibres."

I gave as my diagnosis, on November 11, the following statement:—

The spasms in this patient have been strictly unilateral, and with rare exception confined to the paretic side. They have been entirely of the tonic type without the least evidence of clonic movement. Such spasms have generally been regarded as subcortical in origin. They resemble the "cerebellar fits" of Hughlings Jackson, although they differ in being unilateral. There is only one part of the brain that I know of at which a lesion is capable of producing paralysis of the ocular sympathetic supply on the same side as the hemiplegia, and that is in the subthalamic region. A lesion on the left side in this region would be capable of producing a right hemiplegia, a right hemihypæsthesia, and a paralysis of the right ocular sympathetic, because there is evidence from the work of Karplus and Kreidl that the sympathetic fibres in the cat decussate in part about this level; at any place below this level it would require two lesions, if above the motor decussation, to produce a right hemiplegia and a paralysis of the right ocular sympathetic (as I have determined from my own observations). There has been evidence, obtained by lumbar puncture, of meningeal hæmorrhage in this case, but the greatly increasing frequency and severity of the right-sided spasms are

suggestive of some focal lesion. I have in my collection a specimen in which the rupture of a small vessel in the subthalamic region produced a meningeal hæmorrhage. It is possible that a similar lesion is present in this case.

In 1916 [8] I had occasion to call attention to the great variety of disorders attributed to the corpus striatum, and since then the number of "striate" affections not only has not been reduced by proper classification and relegation to other parts of the brain, but it has been increased by the addition of other symptom-complexes. The very terms employed lead to confusion. Striate may refer to the entire corpus striatum, or it may be confined to the putamen, or possibly to the putamen and the nucleus caudatus. This is an unfortunate use of terms. It would be better if we were to employ the old designations of globus pallidus, putamen and nucleus caudatus; or else paleostriatum and neostriatum; or if we accept Kinnier Wilson's striking terminology we may speak of the old motor system and the new.

In 1916 the number of corpus striatal disorders was great. I could mention Wilson's "Progressive Lenticular Degeneration," "The Pseudo-Sclerosis" of Westphal and Strümpell; "Huntington's Chorea"; "Parkinson's Disease," "Spastic Pseudo-bulbar Paralysis with Contractures and Choreo-athetoid Movements" of Oppenheim and Vogt, and Freund and Vogt; Oppenheim's "Dystonia Musculorum Deformans," and "Progressive Athetosis." I added v. Bechterew's "Hemiatonia Apoplectica," certain forms of carbon monoxide poisoning, and the family form of pseudo-sclerosis. Since then epidemic encephalitis has exerted its baneful influence, and produced a further grouping of striatal symptoms, notably of the spastic paroxysmal types, and has enriched our knowledge of the functions of the corpus striatum.

When we consider that the present great interest in striatal disorders was aroused chiefly by Kinnier Wilson's paper on "Progressive Lenticular Degeneration," in 1912, only fourteen years ago, and that at that time it was so difficult to ascribe function to the corpus striatum, that some questioned the activity of this great mass of gray matter, we are amazed by the vast amount of function of the most varied type now attributed to this basal structure of the cerebrum. Surely all this confusion demands a Babinski to do for striatal complexes what was done for the luxuriant growth of hysteria. A recent attempt in this direction by Hirsch, in his paper on bulbo-spinal and cerebellar attacks, to which I shall refer more fully later, and by Foerster, in his splendid study of the conduction paths of pain sensation, are

praiseworthy. Hirsch has attributed tonic attacks not only to the corpus striatum, but to parts below it.

Our knowledge of the representation of function in the corpus striatum is very limited. We are faced with the astonishing clinical observation which I as well as others have made, that after epidemic encephalitis we may have the Parkinsonism confined to a single limb, usually the upper, and are led by this to believe that the limbs must be represented separately in the corpus striatum. Clinico-pathological investigations may elucidate this problem, for we are without the means which has been of so much value in cerebral cortical motor localization, viz., the use of electrical stimulation, inasmuch as the corpus striatum in the higher animals does not, when electrically stimulated, give rise to any recognizable skeletal movement, according to Kinnier Wilson. He says we cannot on the grounds of comparative anatomy and physiology consider the corpus striatum and motor cortex comparable without a good deal of qualification. The motor functions of the corpus striatum may stand to the rest of the old motor system somewhat in the relation of the higher motor cortex to the motor cortex proper.

In reference to this subject Foerster says no evidence has been obtained in man showing that electrical irritation of the pons and medulla oblongata will give convulsions. Our knowledge of the motor effect of electrical irritation of subcortical centres in man is small. He has twice seen severe epileptic convulsions develop in man during operation on the posterior cranial fossa, as the result of pressure on the medulla oblongata; they were part of other symptoms of such pressure. He has repeatedly seen tremor, first in the contralateral, then in the ipsolateral, half of the body resulting from strong faradic irritation of the head of the caudate nucleus, and these experiments were not made on epileptic patients in whom the irritability was increased beyond the normal. He has never obtained motor response from irritation of the cerebellar cortex, but electrical irritation of the cerebellar nuclei in man has caused tonic spasms of the ipsolateral limbs, and turning of the eyes and head toward the side irritated, which did not persist after the irritation ceased.

It seems very unpromising, therefore, to expect speedy determination of function in the corpus striatum as applicable to the segments of the body separately, and Parkinsonism of a single limb must not be regarded in the light of paralysis of motor function from a lesion in the striate body, but as the result of a limited striate lesion in some definite part which removes the "tone control" of the affected limb.

The two peculiar cases in which brief tonic attacks occurred without the slightest evidence of clonic movements, mentioned in this paper, have led me to search the literature for an explanation. Where is the lesion which can produce such attacks? Do the reports of cases in the literature in which tonic fits, to employ the phraseology of Hughlings Jackson, were attributed to the striate body afford an explanation for these brief paroxysmal attacks limited in the extent of area involved; or shall we consider that mesencephalic or subthalamic fits may occur, and what relation do these bear to Hughlings Jackson's cerebellar fits? I hesitate to increase the striate complexes by adding the large group of paroxysmal tonic fits or spasms to the striate body with the designation employed by Wimmer of striate epilepsy.

Kinnier Wilson [11] is responsible for the statement that in the decerebrate animal Graham Brown has shown that unipolar stimulation of the cross section of the mid-brain, obtained by decerebration at the level of the anterior colliculi of the corpora quadrigemina at a point entirely dorsal to the cortico-spinal tract in the crus, constantly produces a definite, specific postural motor reaction. The head is tilted back, the homolateral arm is flexed and the opposite one extended; the leg of the same side is extended and the opposite one is flexed (as a rule). This position of the limbs on the stimulated side corresponds to the attitude of the limbs in Case 2 of my paper, but as hemiplegia had been present, and the tonic spasms did not develop in the paretic limbs until after the hemiplegia had diminished, it is difficult to believe that the stimulation was on the same side as the tonic spasms.

Wilson speaks of tonic fits, and includes in this classification the "cerebellar fits" of Hughlings Jackson, so-called, which he does not consider the best name to give to them. They show striking resemblance to the positions assumed in decerebrate rigidity. The grave, hysterical convulsive attacks, as shown by Richer's drawings with the *arc de cercle*, resemble those produced by mesencephalic transection. In this connection I may mention that the Vogts have placed certain hysterical signs in the striatal region.

In all Wilson's descriptions of tonic fits the condition was dissimilar to that which I am now describing; the position of the upper limbs was very different, and the attacks involved a greater extent of the upper limbs.

The recent study of Foerster on epilepsy is a valuable contribution. In his opinion every part of the central nervous system, cortex, subcor-

tical centres, spinal cord, can be the starting point for epileptic attacks. The spinal cord, separated from the brain, may be irritated by absinthe and other means, to the production of tonic-clonic spasms in animals, but no similar observations have been obtained in man.

Since the investigations of Schroeder v. d. Kolk and Nothnagel, it has been known that epileptic spasms may be produced by irritation of the pons and medulla oblongata. When the cerebral cortex is removed fits may be obtained through the subcortical centres. Decerebrate animals possessing only pons, medulla oblongata and spinal cord may develop tonic-clonic spasms. It has always been questioned whether the cerebral cortex is necessary in the production of clonic movements. Horsley, Ziehen, Rothmann and others regarded the cortex as necessary for the clonic component, but recent investigations have shown that this view is not correct. Dandy, from recent experiments [1] on dogs, arrives at a very different conclusion. He asserts that the motor cortex is alone responsible for clonic convulsions in the dog.

Foerster says it is certain that hæmorrhage, abscess, or tumour of the cerebellum, either in the cortex or white matter of the cerebellum, may cause attacks of tonic spasms of the ipsolateral limbs, with turning of the eyes and head toward the side of the lesion. In bilateral lesions bilateral tonic attacks occur in the limbs, with opisthotonos of the head and back. In one of his patients, in whom—following otitis media—arachnitis developed with a meningeal cyst on the lower surface of both cerebellar lobes and vermis, epileptic attacks occurred in which the patient, stiff as a board, was drawn backward with so much force that the occiput was severely injured. These attacks were associated with loss of consciousness, rigidity of the pupils and resulting amnesia. The attacks could be produced by caloric irritation of the N. vestibularis and ceased when the cyst was removed.

Hæmorrhage or tumours of the pons or cerebral peduncles have repeatedly caused epileptic attacks, either unilateral or bilateral. Foerster found in such cases tonic extension spasm of the contralateral side in unilateral lesions, and in bilateral lesions bilateral tonic spasms, with opisthotonos of the head and back, trismus, tonic ocular muscle spasm, with the eyeballs usually upward, and stertorous breathing. He has seen severe tonic extension spasm from lesion of the ventricles. There can be no doubt that even in man epileptic attacks may be caused from subcortical centres. These attacks are chiefly of tonic character, but clonic spasms have also been observed. It is to be noted that the position of the limbs is described as that of extension.

We have no knowledge of epileptic attacks in man when the cortex is absent. Whether a difference in this respect between man and the lower animals exists is unknown. There are very few observations in man in which epileptic attacks have arisen from the spinal cord. He does not think it is possible to separate the cortical, subcortical and spinal components of an attack.

In another paper he enters into further details. He has seen irritation phenomena from the corpus striatum, viz., tremor and intense tonic spasms, seldom unilateral, more commonly bilateral, implicating the trunk and head, which occur especially from hæmorrhage into the ventricles. In a case of hæmorrhage from the choroid plexus of the right lateral ventricle he observed these spasms occurring every four to five minutes. They began always by comparatively coarse tremor of the limbs, trunk and jaw, on which followed severe tonic spasm, trismus, opisthotonos of the head and trunk, the upper limb was strongly adducted and rotated inward at the shoulder, it was extended at the maximum at the elbow, the hand was in extreme pronation and flexion, the fingers and thumb were flexed to the maximum, the lower limb was in extreme extension and adduction, the foot was in pronounced supination and plantar flexion, the toes were extremely dorsally flexed, but in part plantar flexed. Other signs also were present. The attacks ceased with tremor of the limbs, and there remained slightly increased tonicity of all the muscles, with here and there mild myoclonic twitchings and tremor.

The same phenomena appear in ventricular meningitis. Foerster says he has seen them repeatedly when a brain abscess ruptured into the ventricles. The spasms usually were severe, but in some instances the attacks consisted of slight tremor and mild tonic spasm. Similar attacks he has observed after too rapid escape of fluid by callosal puncture.

These attacks were with full extension and inward rotation of the upper limb, with disturbance of the pulse, breathing and temperature, with flushing of the face and entire body. They resemble closely the tonic fits which Wilson describes, and are not closely comparable with the tonic fits I am describing. They resemble frequently repeated attacks of decerebrate rigidity, and the upper limb as well as the lower appears always to have been fully extended.

The peculiar form of epilepsy which Knapp describes [7], under the name of "epilepsia spastica," is a form which he believes has its origin in the basal ganglia, especially in the putamen and optic thalamus, but

the attacks are different from those in which I am interested at present. The case he describes is as follows: A boy, 7 years of age, received a severe head injury, striking his head in a fall. Typical epileptic attacks began when he was ten years of age, and increased in severity and frequency as the years passed. So far this is the history of a typical case of epilepsy, but gradually the patient became spastic and incoordinate, with exaggerated patellar and Achilles reflexes and Babinski's sign. He showed much mental failure, his speech became slow and difficult, his muscles became rigid. Most of these symptoms disappeared under large doses of bromide, even the spasticity, the patellar clonus and ankle clonus and the Babinski sign. When the bromide was discontinued the symptoms returned, and a clinical picture resembling paralysis agitans, or pseudo-bulbar palsy, or Wilson's progressive lenticular degeneration, developed.

Knapp [7] asserts that this is a peculiar form of epilepsy, not merely an organic condition associated with epilepsy, because of the disappearance of the spasticity, of the marked diminution of the paralysis agitans symptoms, such as the muscular rigidity, of the disappearance of the restricted voluntary movements, and of the disturbed speech under bromide therapy. Although he places the lesion in the striate body his description is different from that of the striate epilepsy described by Wimmer.

Sterling [10] refers to spastic phenomena as a part of the syndrome of epidemic encephalitis, and he reports ten cases of unquestionable acute encephalitis. In one case during the acute stage a spasm of the left lower limb developed, fixing the limb in the position of equinovarus, with the big toe in dorsal flexion, and the other toes in plantar flexion. This spasm was permanent for three weeks, even during the night, was very painful and then ceased.

In another case spasm in the upper limb caused flexion of the forearm lasting six and a half hours, with moderate pain in the biceps muscle and the muscles of the forearm. These spasms disappeared after three weeks.

In another case spasm of the thenar muscles occurred with very painful apposition of the thumb. These spasms occurred several times in the day and lasted from some minutes to one hour. Only twice in this case was painful spastic flexion of the toes of both feet observed.

He observed spasms of the facial muscles throughout the day and disappearing at night. He has seen torticollis develop after the acute attack, as well as persistent trismus, suggesting tetanus. In all the

examples quoted above the spasm of muscles either was chronic or very prolonged but intermittent, and it is noteworthy that the spasms were confined to a single limb. More interesting and important are his observations relating to paroxysmal spastic phenomena. In one case toward the end of the first week of the encephalitis painful flexor spasms developed at the left knee, and lasted from fiteen minutes to one and a half or two hours, immobilized the limb at the knee in an angle of 35°, and the hypertension could be overcome only by considerable force which increased the pain. Consciousness was preserved during the attacks, and the great majority of the attacks were stereostypic, differing only in the duration. Relaxation of the spasm and cessation of the pain occurred very quickly. The attacks persisted thirteen weeks and disappeared gradually.

In another case with very similar symptoms there developed during the third week of these symptoms in addition paroxysmal spastic attacks which caused flexion of the left thigh on the abdomen and flexion at the knee almost at right angle and maximal flexion of the left elbow. Five attacks of this type were observed during two and a half weeks, the longest lasted forty minutes, the shortest twelve minutes. The spasms of the upper limb were moderately painful, those of the lower limb were much more painful. There were no clonic movements.

In another case pain developed in the right upper limb with bilateral spasms confined to the fingers. The position of the hands was like that of tetany, i.e., strong flexion of the proximal phalanges, with extension of the medial and distal phalanges, adduction of the four fingers and great adduction of the thumb, so that the thumb was covered by the other fingers. This spasm could be overcome passively and the pain was of moderate intensity. It occurred daily for nine days and lasted two to three hours, then disappeared. This case has resemblance to both the cases I report in this paper. Sterling suggested the name of "extrapyramidal epilepsy" for his cases.

Wimmer [13] has studied this subject carefully and believes the tonic syndrome is extrapyramidal, affecting the neostriatum, the putamen and possibly the nucleus caudatus. In his case tonic spasms were the only sign of disease during a period of about five years, and for several months they were unilateral. The attacks at first suggested epilepsy, and they were so regarded by neurologists on two occasions. For a period the patient, a boy, had generalized tonic spasms with initial cry, cyanosis and loss of consciousness for some minutes, but no clonic

movements. On one occasion only he bit his tongue, but he had no involuntary evacuations. He did not have interparoxysmal hyperkinetic phenomena. Indeed Wimmer himself at first diagnosed a possible epilepsy. After five years severe contortions of the trunk and limbs between the paroxysmal spasms, speech disturbances, tremor of the hands and athetosis developed, at times he assumed the position of decerebrate rigidity. Clonic movements never occurred. Wimmer called this striate epilepsy. It is interesting to recall that typical epilepsy may be associated with hyperkinesis of striate origin, as tremors, choreic movements, myoclonia, &c.

Hirsch refers to interesting experiments of Economo and Karplus, in which they demonstrated that section of the foot of the cerebral peduncle (pes pedunculi) of each side in the cat and ape did not affect cortical epileptic attacks, and they concluded that tegmental tracts must be concerned in the conduction of impulses. It would seem therefore that the extrapyramidal tracts play an important rôle in ordinary epilepsy.

Hirsch [5] states that strychnine poisoning causes tonic-tetanic attacks, and it is definitely determined that these have their origin in the spinal cord. When the posterior roots of the frog are cut strychnine convulsions do not occur, from which it is concluded that these convulsions depend on irritation transmitted by posterior root fibres. He reports a case of a small neuro-epithelioma of the fourth ventricle with syringomyelia of the upper cervical cord. Attacks in this case began with paræsthesia in both upper limbs and hands, followed by a feeling of rigidity of the whole body, including the neck. It was believed that the effect of the tumour on the underlying vagus nucleus was the cause of the attacks, and Hirsch believed the cerebellum could be excluded.

In Case 2 of my paper a phenomenon was observed which has not been mentioned in any case of subcortical epilepsy, viz., paralysis of the ocular sympathetic on the side of the tonic spasms. I have studied the course of these fibres in a paper published in 1920 [9]. A lesion in the left subthalamic region, probably a small hæmorrhage, might be the cause of the right hemiplegia and paralysis of the right ocular sympathetic, with development of tonic fits as the hemiplegia diminished in intensity. It may be that the striate body is an important part of the sympathetic supply. John I. Hunter [6] remarked: "It is interesting that Ariëns Kappers has pointed out that the corpus striatum develops near the frontal end of the sulcus limitans, which according to Herrick and others ends in the preoptic recess. He suggests on

these grounds this body "may be of sympathetic origin," and again: "It has been shown (Barbour) that the vasomotor centres are under the control of the heat centre of the corpus striatum. Warming reduces the body temperature and cooling of the corpus striatum increases it. This is especially interesting in the light of Kappers' suggestion and the clinical effects on movement of lesions of the corpus striatum. For it is evidence of another sympathetic effect subserved by the corpus striatum."

The work of Karplus and Kreidl, quoted in my paper of 1920, seems to establish the existence of an important sympathetic centre in the subthalamic region, but there is still much doubt as to how the fibres from this centre get to their point of exit from the spinal cord; certainly the doubt is very great as regards man. It would seem that in the cat the subthalamic centre has more control on the contralateral eye than on the ipsolateral eye, and this influence is even greater in the ape than in the cat. I gave also my reasons for believing that in man the oculo-sympathetic fibres do not decussate, or at least in very slight degree, in the pons or below this in the medulla oblongata or cervical cord. I reported also a case in which paralysis of the oculo-sympathetic fibres was present on the side of a hemiplegia.

It seems, therefore, that in Case 2 the lesion must have been in the subthalamic or striate region. Foerster seems to favour the subthalamic theory. He says it is not yet definitely known where the afferent visceral fibres end, possibly in the gray nuclei of the subthalamus and the tuber cinereum. In another place he says the afferent tract of the sympathetic system ends in the optic thalamus.

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MICROCEPHALY AND DIFFUSE GLIOSIS: A CLINICO-PATHOLOGICAL STUDY OF FOUR CASES.

BY WALTER FREEMAN, M.D.

Senior Medical Officer, Saint Elizabeth's Hospital, Washington, D C.
(From the Neuropathological Laboratory, Philadelphia General Hospital, and Blackburn Laboratory, Saint Elizabeth's Hospital.)

DIFFUSE sclerosis of the brain still presents a number of unsolved problems in spite of the considerable amount of work done upon the disease. Various types have been separated off from the main affection, yet among those remaining there is still a considerable overlap. Cerebro-macular degeneration (Tay-Sachs disease), tuberous sclerosis, and Schilder's encephalitis periaxialis have been well defined by various authors, but there is still confusion in regard to the anatomic delineation of the Westphal-Strumpell pseudosclerosis, diffuse gliosis as such, and the association of a partial diffuse gliosis with microcephaly. It has seemed to me in going over the clinicopathologic reports of a number of these cases that these three may be slightly different manifestations of the same affection, either taking place at different times in the development of the individual, or affecting different parts of the central nervous system.

The cases on which this report is founded show so many characters in common that they seem worthy of separation from the still large group of the diffuse glioses. Clinically, there is little except the size of the head to distinguish the affection from other forms of diffuse gliosis. The patients present the marked muscular rigidity with tonic fits, progressive idiocy and terminal wasting common to all glioses. Pathologically, however, there is found no degeneration of the ganglion-cells as in Tay-Sachs disease, no symmetrical degeneration of the subcortical white matter as in Schilder's disease, and no cortical hypertrophies or subependymal tumour masses as in tuberous sclerosis. The small size of the brain and the softness of the hemispheres distinguishes the affection from the universal gliosis with enlargement known as macrocephaly.

At necropsy the brain presents evident maldevelopment. The

cerebrum is small, particularly in the frontal portions, and the convolutional pattern is simple. The hemispheres are soft, and in young children almost diffluent. In strong contrast to this, however, is the condition of the basilar portions of the brain. The cerebral peduncles, pons, medulla oblongata and parts of the spinal cord appear perfectly formed, but unduly white, and palpation discloses a firmness such as is encountered normally only in the brain fixed in formalin.

Histologically, also, the structures are practically normal in Weigert and Nissl preparations, yet stains for fibrillar neuroglia show an enormous increase. There is some increase in the number of glia nuclei, but not at all in proportion. Fat stains on areas which are not severely affected by the fibrous neuroglia overgrowth show many minute globules of red colour in the microglia-cells, sometimes silhouetting the cells in a remarkable manner. With this there is practically no bleaching of the myelin sheaths. The lining of the ventricles is made up of columnar palisade ependyma often pushed up into papillæ, or snared off into islands by fibrous glia overgrowth. The central canal of the cord is wide open, but perfectly formed. The fissures of the cord are extremely marked, but there is no degeneration of any of the tracts. Inflammatory phenomena are lacking.

Cases of this disease, or rather of this variety of diffuse gliosis of the brain combined with microcephaly, are reported in more or less detail and with but few variations by Rolly (1901) (two cases, twins), Zappert (1910), Maiss (1896), Marchand (1924), Spiller (1905) (three cases), Anton (1889), Ganghofner (1895). The disease is usually one of infancy, although it may advance to childhood, and Marchand's patient finally died at the age of 17, the oldest that I have found reported. Most of the children die under one year of age. Degenerate parents, and those with chronic diseases, are frequent in the antecedent histories. Rolly's twins were the fourteenth and fifteenth in the family. Early diseases cannot be incriminated, but postnatal cyanosis is mentioned. Usually born at full term, these children from the first manifest defective development. The sucking reflex is abnormal. There is no recognition of objects or of people. Muscular rigidity is early and progressive, ceasing at first during sleep, but later persisting continuously, and often going over into tonic fits. In these attacks the arms are flexed, and the legs extended, the neck retracted, and breathing suspended for a few moments. The infants cry spasmodically much of the time. Voluntary movements are impossible on account of the immediate rigidity that accompanies each effort. Near the close of the

disease the child may be supported by the head and feet alone. Tendon reflexes are either exaggerated or completely suppressed by the extreme rigidity. A Babinski reflex is often wanting even in young infants. No defects in the peripheral innervation of the face, eyes or mouth, can be noted, although there is often a pseudobulbar motor defect. Sensory stimuli are reacted to in a brusque manner, often with universal tonic spasm. Athetoid movements are observed, but tremors are inconstant. The development of intelligence remains in abeyance or even regresses, and the course is progressively downward without remissions. Unless some intercurrent disease sets in, the patients die of inanition, or starvation, because of difficulty in taking nourishment.

Report of Cases.

Case 1.—Martha S., Russian, aged 3, was admitted to the service of Dr. J. Hendrie Lloyd at the Philadelphia General Hospital on December 13, 1922, and died a week later. Diagnosis: Microcephalic idicey, broncho-pneumonia.

She was the first child of a woman aged 25, whose husband had died of pneumonia a month before the child was born. Birth was natural and rapid, there was no history of cyanosis. On the third day the infant had a generalized convulsion. She nursed badly from the beginning, interrupting it by curious jerky movements and by chewing the nipple without sucking. She always breathed rapidly and spasmodically. When seven months of age she again had a series of convulsions that left her prostrated. The first teeth appeared at thirteen months, their eruption being associated with crying spells and vomiting. The child had never been sick, had had no exanthemata. She never learned to sit up. There was no instance of nervous disease in the antecedents, though the question of syphilis was unsolved.

Examination on admission disclosed an overweight child lying on its back, with its eyes closed, screaming continuously. The whole body frequently went into tonic spasms, in which the neck was retracted, the fore-arms flexed with the hands clenched, the back bowed, the lower extremities strongly extended with the toes curved under the foot. The head was small, the forehead receding. The facies suggested the mongolian type, but presented no epicanthus; the face itself was asymmetrical. The pupils were equal and regular, and responded to light. There was no ptosis, and the ocular movements seemed normal, but left internal strabismus was noted at one examination. A few teeth were present; the tongue was normal. Respiration was rapid and intermittent in type, ranging from 40 to 100 per minute on various occasions. There were no abnormal physical findings in regard to the lungs or heart, although the pulse was abnormally rapid. The abdominal muscles were in spasm, defeating attempts at palpation. The arms were flexed and adducted, the hands clenched and contracted in an irreducible fashion. Any attempt to straighten them was met with intense muscular spasm, and the child would often go into generalized tonic contraction in which all the muscles of the body

were tetanized. The legs were in forceful extension most of the time. Reflexes were exaggerated when not entirely suppressed by the spasticity. Ankle clonus and the Babinski signs were not elicited on this account. The child was very resistant to examination, screamed when handled, and went into tonic spasms at the slightest provocation. The peculiar spasmodic opening of the mouth with the emission of an almost noiseless cry was noted on many occasions. During the short intervals between the tonic fits the child was very restless, had continuous athetoid movements of large amplitude and great force, throwing its body this way and that in the crib. Bromides suppressed these constant movements for a short time only. The face became cyanotic during the attacks of generalized rigidity.

The child was acutely ill on the day after admission, and moist râles were noted at the base of the lungs. The cardiac action became very rapid, although no murmurs were audible. The temperature rose steadily until it reached 107° F. just before death. The urine contained a trace of albumin, and the examination of the blood revealed hæmoglobin 74 per cent., white blood-cells, 10,300 per c.mm.

Necropsy was performed nineteen hours post mortem by Dr. S. S. Schochet. It revealed marked toxic degeneration of thé cardiac muscle with the presence of subepicardial purpuric spots. The lungs were largely consolidated by confluent broncho-pneumonia. Liver, spleen and kidneys were the seat of marked cloudy swelling and congestion. Post mortem heart-blood culture yielded *Streptococcus viridans*.

The head was decidedly short in its antero-posterior diameter. The forehead was receding, and the skull bulged somewhat on the sides. The brain weighed 680 grm. It showed deficient development, especially in the frontal poles, which were shorter than normal and quite narrow. The Sylvian fissure was incompletely developed, there being only a very indistinct groove between the temporal pole and the operculum. The fissures were normally prominant, the convolutional pattern was somewhat simpler than normal The brain, as a whole, was firmer than normal, maintaining its shape well when laid open by a cut through the corpus callosum. On palpation this firmness was noted particularly in the hippocampus and the basal ganglia. The pons and medulla oblongata showed it very markedly. The hardness was diffuse, but did not extend to the cerebral cortex or its underlying white matter, except in the region of the cornu ammonis. The ependyma lining the ventricles appeared smooth to the naked eye. The spinal cord presented the same exaggerated firmness in three different locations, being soft and flaccid in the other parts. Where the firmness was pronounced the spinal cord stood upright when grasped below, much as one fixed for a time in Müller's fluid. Sections through the brain-stem revealed no gross abnormalities in architecture. The substance was very firm, retaining sharp edges when cut. The cross-section appeared somewhat whiter than normal but with strongly outlined gray matter. The various medullary nuclei could easily be recognized by their colour contrast with this whiteness.

After fixation in formalin further sections revealed extensive hardening of the basal ganglia, and even of the white matter beneath the cortex, although there was no atrophy and no change in colour, except possibly an exaggerated pallor.

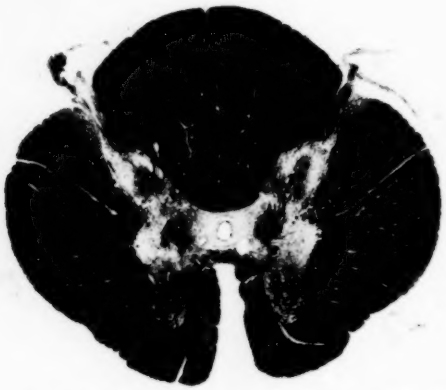

FIG. 1.—Spinal cord of *Case* 3, thoracic region, Spielmeyer stain. The myelinization is good. The septa and fissures are more prominent than normal, and central canal is wide open with a wide ring of clear tissue about it.

FIG. 2.—Spinal cord of *Case* 3, thoracic region, glia stain. The density of the glia feltwork is seen about the central canal as well as about the margin. The septa are extraordinarily prominent.

Microscopic sections of the cord in the regions designated as soft in the gross description revealed normal findings. Aside from a somewhat patent central canal there was no pathologic lesion demonstrable. The myelin

sheaths appeared normal; there was no fat. In contrast to these areas, the ones described as hard and white were smaller and more compact than the others, although alternating with them. The ventral fissure was wide, and the various septa deep and rather wide (fig. 1). The dorso-lateral septa where the nerve roots entered were almost sufficiently pronounced to be termed fissures. There was generalized diffuse thickening of the marginal neuroglia fibrous layer, and heavy strands of delicate fibres ran down into the white matter between the myelin sheaths, binding them together very firmly (fig. 2). The central canal was wide open, its ependyma arranged in palisade fashion,

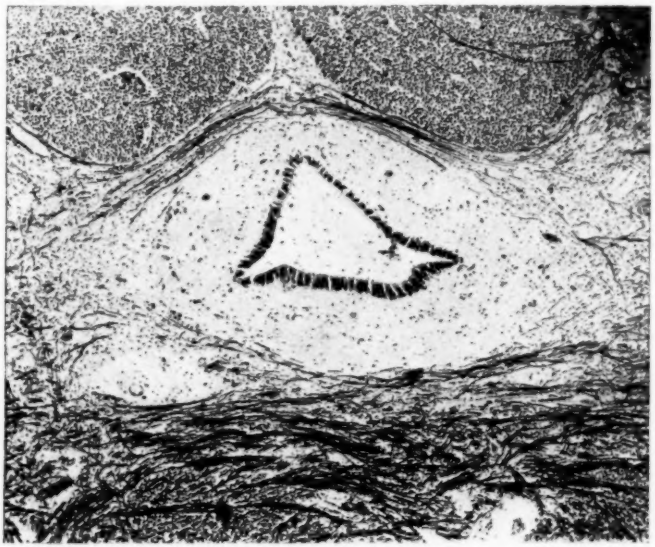

FIG. 3.—Spinal cord of *Case* 1, lumbar region, Freeman stain. The open central canal is lined with ciliated ependyma. Surrounding it is a pale space without any nerve-fibres.

the cells retaining their cilia (fig. 3). About the central canal there were numerous ependymal cells spreading out laterally, and in one place there was a tendency toward the formation of a subsidiary central canal. The gray commissure was enlarged, appearing practically hyaline in the cell stains, but under specific treatment showing enormous numbers of delicate glia fibrils running in a compact fashion mostly tangential to the canal (fig. 4). The nervous structures of the gray matter of both horns were essentially normal, but in all parts these same delicate strands of glia-fibres could be seen running in all directions, binding the tissue into a compact mass. There was very striking gliosis of the white matter also, not visible so much in the cross-sections of the cord as in longitudinal sections. Along the course of every

myelin sheath a number of delicate glia-fibrils could be traced. In cross-section the cut ends of these fibrils appeared as a circle of minute dots about each myelin sheath. There were no large glia-cells, and the small nuclei did not seem to be especially increased in number. Small amounts of fat were found about the vessels of the ventral and dorsal horns of the spinal cord, sometimes enclosed in phagocytic-cells, sometimes free in the meshes of the adventitia. A diffuse deposit of fine droplets was found in the gray matter of some sections. Some of the vessels in the white matter of the cord were similarly affected. The myelin sheaths, however, revealed no abnormalities,

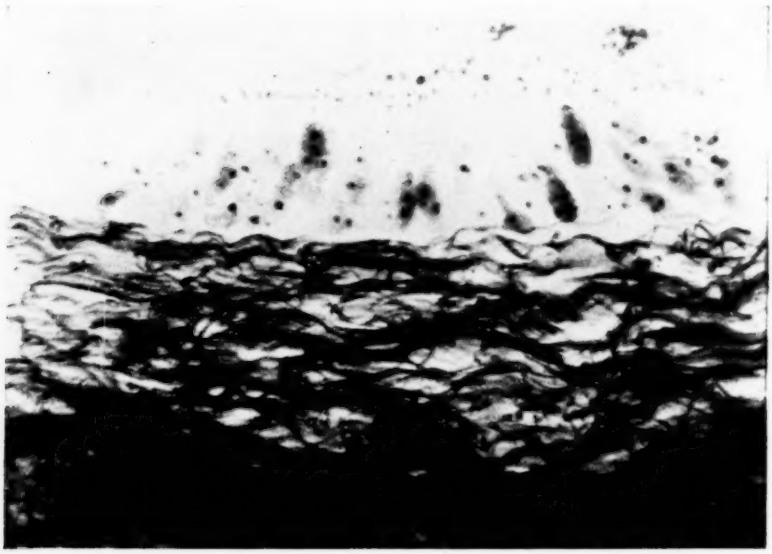

FIG. 4.—Spinal cord of *Case* 1, cervical region, glia fibre impregnation. The space about the open central canal is traversed by large numbers of glia fibres.

being present in normal numbers. There was no degeneration of any of the columns in the ordinary sense of the word. Cell stains showed normal cellular arrangements in both ventral and dorsal cornua. The meninges and blood-vessels showed no disease. The nerve-roots were normal.

The medulla oblongata also showed very numerous fine glia-fibrils at the periphery and about blood-vessels. Especially in the floor of the fourth ventricle, the subependymal gliosis was marked and the ependyma was raised and depressed at the angles to a very marked degree. Some of the ependymal-cells seemed to send long streaming fibres deep into the subjacent tissue, there to be bound up in the very great network of densely woven glia-fibres. The

gliosis was well marked in both gray and white matter. Occasionally a gigantic glia-cell was observed, with processes extending in various directions, a true monster cell. With all this, however, there seemed to be no disturbance in the essential architecture of the medulla. The cell groups were rightly placed, and seemed to have developed normally. The cells were normal in shape, and most of them retained their chromatin bodies intact. Silver preparations showed apparently an undiminished number of nerve-fibres. A small amount of fat was observed in the gray matter, especially in the dilated perivascular spaces. Vesicular and minute compact glia nuclei were present in moderate excess.

The pons again was the seat of very marked fibrillar gliosis with some increase in the number of small nuclei, but the cell stains and Weigert preparations showed little or nothing out of the ordinary. The ependyma was elevated into papillæ in many places, and elsewhere little nests of ependymal-cells were found separated from the ventricular cavity. The cells of the locus cœruleus contained a very pale pigment. The pontile nuclei were well formed, and the myelin sheaths of all tracts appeared perfect. Fibrillar gliosis was the only important finding. Fat was practically absent.

In contrast to the compact tissue of the brain-stem and spinal cord, the cerebellum presented an appearance that suggested great shrinkage during technical procedures. The granule and molecular layers were frequently widely separated, and the Purkinje-cells were fragmented. There seemed to be no atrophy, however, and no overgrowth of the glia even at the Purkinje level. The white matter and central nuclei appeared to be intact. There was no fat release.

The picture of diffuse fibrillar gliosis, especially about the aqueduct and marginal layers, was again well marked in the mesencephalon. The locus niger showed no pigmented cells (resembling in this respect our control material), but otherwise the section in both cellular and myelin sheath preparations presented a normal picture.

Glia overgrowth in the thalamus was striking in this instance, somewhat in contrast to the other cases studied. Besides the strong *couche fibrillaire* beneath the wavy ependyma there was an interlacing feltwork seen in this part of the brain almost as marked as at lower levels. Very large, almost bizarre glia forms, were encountered, with long wavy processes. Small forms with relatively few staining fibres were seen in considerable excess over the normal. In the thalamus there appeared to be a noticeable reduction in the number of nervous elements, and those remaining often showed swelling and vacuolization of the cytoplasm. There was no intraneuronal fat, but dust-like fatty globules were found in considerable abundance both free and enclosed in glia-cells of the wandering type. More compound granule-cells were found in the perivascular sheaths than elsewhere. The hypothalamus showed marked diffuse fibrillar gliosis and a small amount of fat, but nothing else.

The globus pallidus was small in size and rather paler than normal in Weigert preparations. Perivascular spaces were large, bounded by thick feltings

of glia-fibres. The cells appeared normal, although there was evident deficiency in the number of myelin sheaths present. Glia-fibrils appeared to run in numbers along each myelin sheath. Fat was not abundant, and the perivascular sheaths contained only an occasional fat-laden cell.

The posterior portion of the putamen was abnormally pale in Weigert stains. Although nerve-fibres were present in abundance, yet the sheaths for these fibres seemed poorly developed. The area was not at all localized, did not resemble an infarct, nor even an area of degeneration, for phagocytic-cells were only rarely encountered, and none of the large giant forms usually associated with such areas of demyelinization in Schilder's encephalitis. There was an increased number of small glia nuclei, and the fibres were numerous, giving a distinctly blue colour to the naked eye in glia preparations. The fibres ran in every direction, but varied little in size, and they were not tortuous to any notable extent. The number of nuclei was enormously increased, mostly of the compact highly chromatic variety. The blood-vessels appeared more numerous in this region than in the other areas of the putamen, their spaces were enlarged, but there was no endothelial reaction as in syphilis. The small nerve-cells appeared rare in this wealth of small glia-cells. Some large glia-cells were encountered and quite numerous rod forms. Very many of the small vessels were found to be invested with fatty particles, not contained in cells (for the granule-cells were conspicuous by their absence), but lying in the meshes of the connective tissue and in the wide spaces left by the shrinkage of the vessels from the more rigid surrounding glia wall. The large vessels were not thus affected. Fat was also contained in the minute glia-cells with rod-like nuclei, but it did not impart to them the typical silhouette character found in other locations. The dust-like scattering of minute red globules was unlike that seen in the disintegrative processes of later years. It was wholly absent from the control material of a child of 3 years dead of pneumonia. Granules and crystals of deposited stain were not in evidence in the preparations described.

Fat release was also a notable feature of the caudate nucleus. Here the region just beneath the ependyma formed a dumping ground for large amounts of the material, the vessels were surrounded by it, and a few typical granule-cells were encountered with cytoplasm swollen to capacity with fat globules. The ganglion-cells appeared rather widely dispersed on a smooth hyaline background in azure stains, and except in the vicinity of the ventricular wall there was no great amount of gliosis. Some very long straight glia-fibres were encountered running through the hyaline fundamental substance of the caudate nucleus.

The cerebral cortex of this case presented to a more marked degree than the others the general reduction in the number of cells present. The molecular layer was broad, without any notable feltwork of glia beyond the ordinary lamina marginalis. The ganglion-cells were arranged very typically in strands, and stratification was more or less defective. The cells were well separated in most instances, leaving large vacant spaces between them. There was no

overgrowth of the neuroglia in a compensatory fashion ; the minute nuclei were not more numerous than normal. About some of the cells in the deeper layers a few satellite-cells were accumulated, but not in an extraordinary fashion. Nor was there anything peculiar in the morphology of these cells. The ganglion-cells were in a stage of acute chromatolysis for the most part although some appeared shrunken. The mesodermal structures, meninges and blood-vessels presented a normal appearance. Fat was abundant in various places, especially in the hippocampal region. It seemed to be out of proportion to the number of microglia-cells visible in the cell stain, but it frequently silhouetted them in a striking manner. More of it was found collected about vessels than in any other location in the brain, and it was relatively frequent to find compound granule-cells lying in close proximity to the blood-vessels. No fat was demonstrated in the ganglion-cells.

Summary.—A Russian child, aged 3, overnourished, had never developed intellectually. Convulsions began early. The head was small. Intermittent tonic fits with constant screaming were noted during the short residence in the hospital. There was great spasticity at all times. At necropsy, besides the microcephaly there was noted diffuse sclerosis of the brain-stem and basal ganglia without inflammatory manifestations. Further study revealed marked fat release in the cortex, caudate and putamen, with an area of demyelinization in the posterior pole of the putamen. The cortical arrangement was primitive in type.

Case 2.—William C., coloured, aged 8 months. Admitted to the service of Dr. Bradley at the Philadelphia General Hospital, July 12, 1922 ; died September 16, 1922. Clinical diagnosis : microcephaly, subdural abscess.

The only history obtained was that the child had been irritable for two days and that there was a lump on his head.

Examination disclosed a poorly nourished coloured boy quite restless, crying much of the time, especially when handled. There was a smooth swelling in the left parieto-occipital region with slight fluctuation. The head was described as small, though no measurements were given. Pupils responded normally to light, there was no discharge from the ears. Tendon reflexes were exaggerated, but no mention is made in the clinical record of a Babinski sign. The rest of the examination was negative.

The lump on the head was aspirated and about 4 c.c. of thick yellow pus obtained from which *Staphylococcus aureus* was cultured. Free incision of the mass yielded no further pus. Two days after admission it was noted that the child was stuporous, that the Kernig and Brudzinski signs were positive, and that the neck was quite rigid. Spinal puncture revealed fluid under normal pressure, clear, sterile, with a negative Wassermann reaction and no tubercle bacilli. Some antimeningococcus serum was given. The blood-count on two

occasions was normal, the blood Wassermann reaction was negative, and the roentgenogram of the skull was negative for fracture or bone destruction. The urine was negative until just before death, when it showed a heavy cloud of albumin. Blood-chemistry was normal.

Subsequent examinations showed that the child's body was rigid much of the time, that the muscular twitchings were very frequent, and that so-called convulsions in which the baby became stiff all over were repeated at frequent intervals. These were probably the counterpart of the tonic fits in the first case. The child cried in a spasmodic way, making scarcely any sound although the mouth was very widely opened. A week after admission, he had a series of convulsions lasting for more than two hours. The feet stopped first. The right side was more markedly affected by the tonic fits than was the left side. From July 24th to the 29th, there was very marked rigidity of the arms, legs and neck, drawing the baby into the typical decerebrate posture. The clinical picture was varied on this day by the presence of strong muscular twitchings, especially of the face and mouth. These spasmodic attacks greatly interfered with nursing. Crying was practically continuous, but seldom above a whisper. In spite of the negative findings in the cerebro-spinal fluid and normal eye-grounds, it was thought that the rigidity was due to some acute inflammation of the meninges. The child lost weight rapidly and developed a terminal broncho-pneumonia that proved fatal in forty-eight hours, with a temperature of 107·5° F.

The *necropsy*, six hours post mortem, revealed bilateral confluent broncho-pnenmonia, cloudy swelling of the heart, liver and kidneys, and soft enlargement of the spleen. The head was small, the brain weighing 420 grm. The frontal lobes were especially small, with simplified convolutional pattern and wide, deep fissures. In the parietal and temporal regions the convolutions were flattened and broad, and the fissures were practically obliterated. There was moderate vascular injection. The ventricles were not dilated. The membranes appeared normal. The temporal lobes were especially soft upon removal, almost diffluent where the saw had cut them. In contrast to this the pons and medulla oblongata were hard and white, retained sharp edges on being sectioned, and revealed a rather abnormal whiteness on the cut surface. No gross abnormalities were detected aside from the increased consistency. The spinal cord revealed moderate congestion and increased consistency throughout. There was no penetration of the abscess into the cranial cavity and no meningeal inflammation present.

Microscopical examination of the spinal cord revealed a wide open central canal with palisade ependyma surrounding it. Cilia, plasmosomes, and sometimes long radiating fibres were observed. There was about the central canal a dense glia feltwork, making a clear acellular space all about the ependyma. The gray commissure of the cord was enlarged thereby. The ventral fissure of the cord was large, and the various septa, particularly in the dorsal and dorso-lateral regions, were very well defined, making deep dents in the cord. The marginal neuroglia was also a dense feltwork. The internal architecture of

the cord was normal. The cells retained their chromatin bodies. The groups of cells in the ventral horns of the lumbar cord were well demarcated. In the sacral cord a mass of the gray matter was seen in the dorsal column, possibly an artefact, although complete serial sections were not made to prove it. There was no disease of the meninges or blood-vessels.

The medulla oblongata was compact in texture, showing normal arrangement. Weigert preparations showed normal relationships and practically complete myelinization. The floor of the fourth ventricle was notable on account of the dense subependymal gliosis and the snaring off at the lateral recesses of small groups and circlets of ependymal-cells, which were embedded in a tissue that was deeply stained in glia preparations. These ependymal-cells also carried cilia. In one place the formation was so complicated that an ependymal adenoma was considered, but it was probably only an exaggeration of the snaring-off process seen elsewhere. In the medulla some very large glia-cells were seen with many processes reaching out in different directions. They were scattered, however, and did not contain fat. The ganglion-cells took the blue stain normally. Perivascular spaces were large, and bordered by a heavy interlacing of glia-fibres. Unfortunately no special impregnations could be made, but the glia showed up well in phospho-tungstic acid hematoxylin stains. The marginal layer was unusually thick and dense.

In the pons there were seen lesions of the same nature, great overgrowth of neuroglia in all parts, particularly at the boundaries, in the septa, and about blood-vessels, with comparatively few glia nuclei. The ependyma as before was heaped up in places and invaginated in others, giving the appearance of granular ependymitis, due to the increase in the neuroglia feltwork. The tissue was rather dense, but both in cell stain and in myelin sheath preparations showed entirely normal structure. There was no fat in the sections. Here and there were isolated monster glia-cells. Perivascular spaces were wide but contained no infiltrating cells. The cerebral peduncles showed altogether the same picture. The cells of the locus niger contained no pigment.

The cerebellum showed occasional persistence of a few cells of the external granule layer rather later than is usually looked for, but aside from this there was no abnormality noted in the architecture or cytology. The dentate nucleus appeared entirely normal; there was no fat.

The sclerotic process had also affected the thalamus in this case (fig. 5). Besides the great feltwork lining the ventricle there was diffuse extension of the fibrillar gliosis practically throughout this great ganglion, making it compact instead of vacuolated as in the first case. The perivascular spaces were wide, however. Cell preparations gave a picture that was considered altogether normal. The cells were numerous, well stained and of healthy youthful type, showing no fatty pigmentation. Myelin staining revealed normally outlined nuclei of the ganglion and no dropping out of sheaths could be demonstrated. In Scarlet preparations, however, practically a reproduction of the fatty degenerative processes existing in the first case was to be seen, very many fusiform microglia-cells being sharply outlined by their contained minute fat

globules. This fat was stained brilliant red in contrast to the yellowish tinge of ordinary cellular fat in adult nerve-cells. At first it was believed that the ganglion-cells contained fatty globules, but on closer examination it was seen that these large multipolar-cells were of neuroglia type, but sufficiently large to be confused with the former. There was little ballooning up of the phagocytic-cells into compound granule-cells and practically no marshalling of fat-bearing cells into the perivascular sheaths. The fat was diffusely scattered

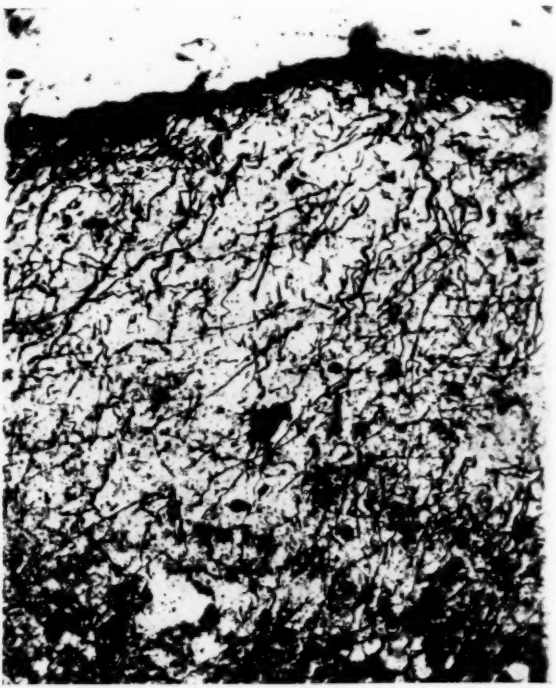

FIG. 5. — Thalamus of *Case* 3. Copper-silver glia fibre impregnation. Beneath the dense subependymal glia boundary are numerous fibres penetrating in various directions.

through the tissue, although localized more particularly in some of the nuclei of the thalamus.

The fatty degenerative process seemed to have passed by the corpus striatum except for a small area in the posterior tip of the putamen where the only area of macroscopic degeneration of myelin sheaths was detected. Here there was pallor in Weigert preparations, and gliosis to be observed in the violet preparations. The gliosis was of the fibrillar type, with an increased number of nuclei, and fat was seen about some of the vessels, although not

in the interstices of the tissue. There were no notable changes in the rest of the corpus striatum except for subependymal gliosis over the head of the caudate nucleus.

The meninges overlying the cerebral cortex were thin and delicate, with vessels of youthful type, showing no infiltration and a perfect elastic lamina. The marginal neuroglia layer was delicate, there seemed to be no overgrowth of either cellular or fibrous elements and no fusion with the pia. Lamination was normal, but the cells were somewhat deficient in number, giving a rarefied appearance to the cortex. Their arrangement reminded one of the fœtal construction, the columnar arrangement of cells being even more pronounced than their stratification. No one layer appeared to have suffered more than another from the absence of ganglion-cells, yet the basic ground substance was relatively increased, and each cell was clearly separated from the others nearby. There had been considerable shrinkage of the cortex during technical procedures, so that a vacuolated appearance resulted. Perivascular spaces were wide. There appeared to be some increase in the number of vesicular glia nuclei over what would be expected at this age, but this could not be certified. There were practically no myelin sheaths visible in the cortex. Again, in Scarlet preparations the glia-cells were silhouetted by their fat content, more markedly in the cornu ammonis than elsewhere, but sufficiently diffusely to be a notable feature. Giant glia-cells were not met with, although occasionally double nuclei were encountered and rarely glia rosettes.

In the hippocampal region the fascia dentata was found to have a reduced number of cells, which were separated, and overgrown by small glia-cells containing fat. The lamina pyramidalis was very much broken up, the cells reduced in number and separated, with blank spaces between. Large and numerous fibrous glia-cells were found in this locality. The nucleus amygdalæ appeared normal.

Summary.—A coloured boy, aged 8 months, microcephalic, was brought to the hospital with an abscess of the scalp. Various severe motor disturbances were noted with normal laboratory findings. Death was due to broncho-pneumonia. At necropsy the basal structures of the brain were all firm and pale, due to fibrous neuroglia overgrowth. The thalamus and cerebral cortex showed marked fatty degeneration with reduction in the number of ganglion-cells, and fat accumulations in the scavenger-cells.

Case 3.—Angelina P., aged 6, was admitted for the fourth time to the service of Dr. Bevier at the Philadelphia General Hospital, on June 23, 1920, and died there April 23, 1923. She was an illegitimate child of Italian parentage. Her mother, who was under treatment for syphilis, had had one healthy child by her husband, who later served a long prison term. The first child by her paramour was apparently healthy. Angelina was the second, and the third died when three months old, of congenital syphilis and malnutrition.

Angelina was born naturally at full term, and appeared to develop normally until the age of 5 months when she had "spinal meningitis," followed a few months later by measles, and influenza in October, 1918. She had been much retarded in development since her first illness.

Examination showed a well-developed and nourished girl, aged 6. The head measured 16¼ in. in circumference (404 mm.) and was very hard. The forehead was receding and there was rather excessive hair growth upon it. She could not walk or talk, scarcely sit up, showed no interest in her surroundings. Physical examination was essentially negative.

Her backward condition may be gathered from the nurse's notes, there being but little else in the clinical record: "Rocking to and fro all night. Cried all day. Makes effort to stand. Incontinent. Enjoyed company of mother, very bright, eats well." And in 1920: "Kicked, would not be covered; is observing. No attempt to stand on feet or walk. Incontinent. Playful, fond of affection. Has a peculiar cry. Bites herself until mouth bleeds profusely. Very obstinate. Bumps head. Sings and chatters, becoming very intelligent. Does not try to use lower limbs. Playing on floor. Rocking to and fro all day."

There is in this record nothing of outstanding achievement, and a physician's note, August, 1922, probably gives a true notion of her condition: "Idiot, vegetative, bed-ridden, incontinent, unable to walk or talk. Stands up and attempts to crawl. Pot-bellied, not epileptic." There was no comprehensive physical examination in the record. The final note stated that she had begun whining during the night of April 22, 1923, was restless at 3.30 a.m. and at 4.30 a.m. was found dead with a distended abdomen, and frothy fluid coming from the mouth.

Examination on the necropsy table showed a poorly-developed but well-nourished girl about 6 years of age. The head was short in its anteroposterior diameter, the brow receding and covered with fine downy hair. The eyes were normal, a small amount of bloody froth issued from the nose and mouth. The skin over the right side of the neck showed an atrophic condition probably due to a burn. The fingers were clenched in the palm and could be straightened only with great difficulty. The arms were flexed. The lower extremities were extended, the feet in strong equinovarus position. There was an abnormally profuse growth of hair over the back, but no hair on the genitalia. Internal examination revealed marked compression of the lungs by an elevated diaphragm which was due to complete volvulus of the sigmoid with great ballooning of the whole large intestine. A small amount of bloody fluid was found in the peritoneal cavity. The other organs showed no important changes.

The brain weighed 985 grm., appearing about normal in size for a child 6 years old. The membranes were thin, the blood-vessels small and not injected. The convolutional pattern was well developed although the frontal poles were short and peg-like. There were no areas of sclerosis palpable over the convexity of the brain, but at the base the pons and medulla were found to

be hard and white. On tranverse section the pons retained its normal shape without bulging, in this respect resembling the brain hardened in formalin. It was of average size and showed no abnormal markings. Above the pons there was no visible or palpable alteration, the basal ganglia were normal. The cervical and lumbar regions of the cord were also white and firm, slightly smaller than the other normal portions. When held upright by these areas there was no bending of the cord. The thoracic portion of the cord was normally soft and flaccid.

Microscopic sections of the cord revealed again a widely patent central canal, oval or triangular in shape, with a very pronounced glia feltwork about it enlarging the gray commissure. The marginal and septal fibrillar neuroglia was very greatly increased, the ventral fissure wide, the various septa deep. In both white and gray matter there was an abundance of fibrous glia not especially marked by increase in the cellular forms. This manifestation was practically absent in the thoracic region of the cord, although here also there was an open central canal. The ependymal-cells lining the central canal sometimes bore cilia, although cytoplasmic granules were rarely seen. Fibres from these lining cells penetrated far into the gray matter about the canal. On each side of the central canal were numbers of ependymal-cells singly, or in groups, although here there was no tendency observed toward the formation of a subsidiary canal. In the thoracic section the central canal was flattened and almost closed. There was only slight fibrillar gliosis about it, in contrast to the cervical and lumbar regions. There was no alteration in the Weigert picture. Fat was found in the vicinity of a few of the small vessels in the lateral column.

The architecture of the medulla oblongata was normal, and the Weigert picture negative for signs of degeneration. Perivascular spaces were large and surrounded by rather dense feltwork of neuroglia, the floor of the ventricle showed the sharp undulations due to the great fibrillar increase beneath the ependyma. The tissue was quite compact. Marginal glia were extensive. No fat was found. The same description applied to the pons, the nuclei of which were well developed, and all fibres well myelinated.

Glia pictures corresponding to the other cases were not found in the mesencephalon. The tectum appeared well developed, the aqueduct presented a normal ependymal glia layer, there was no exaggeration of the marginal fibrillar stratum. The red nucleus presented a number of large cells, the locus niger was beginning to elaborate its characteristic pigment. The pyramidal tracts were well myelinated. Fat was not present.

Weigert and azure preparations of the thalamus presented normal pictures. There was slight accumulation of fat about some of the vessels, and in the hypothalamus some glia-cells contained fat, but scarcely any so-called compound granule-cells were in evidence. Fibrillar neuroglia was in evidence only in the neighbourhood of the tenia, and then only a slight exaggeration of the normal.

The globus pallidus was normal in regard to nerve-cells, nerve-fibres and

myelin sheaths. Rather large glia-cells were in somewhat greater abundance than usual, but the fibres were normal. The perivascular spaces were large. Fat was scattered irregularly, scarcely any in some fields, a diffuse dust-like deposit in others, but a considerable accumulation contained in granule-cells in an area close to the internal capsule. This patch was quite strictly localized, but was not associated with any visible tissue degeneration. Some of the larger vessels in the putamen presented an encircling ring of fat, some of which was intracellular, but there was no other notable change. The caudate was somewhat more affected, fat being present in very numerous small glia-cells,

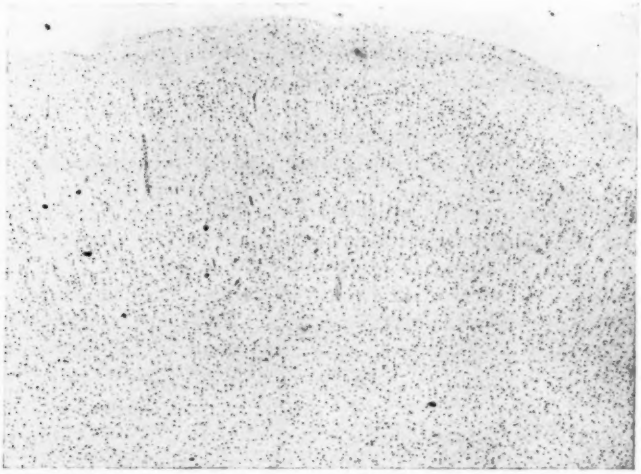

FIG. 6.—Frontal cortex of *Case* 3. The ganglion cells are widely separated and show a tendency to columnar arrangement with imperfect stratification.

especially beneath the ependyma. Fibrillar gliosis in this region was practically absent. The claustrum was about equally spattered with fat, many silhouetted glia-cells being in evidence. Other preparations revealed minimal changes in this structure. The external and outer capsules shared in this manifestation.

Of the various cortical areas the insula was the most profoundly affected by the fatty alteration. The cortex was thin, the alignment of cells perpendicular to the cortex was notable, and lamination was imperfect. In addition there were wide intercellular spaces made up of the hyaline ground substance of the cerebral cortex. The ganglion-cells were of the narrow type, tending to fusiform rather than pyramidal. Many of these showed acute and chronic cytologic alterations, but no severe disease. Scattered about them were numbers of microglia-cells bearing fat globules, these sometimes extending far out into the elongated processes of these cells. These structures bore a

strong resemblance to small ganglion-cells heavily infiltrated by fat, but no fat was actually demonstrable within the ganglion-cells. Fibrillar neuroglia was present in very small amounts. Other cortical areas showed the same undeveloped character as the insula. The perpendicular arrangement was especially striking in the temporal lobe as was almost to be expected, but the frontal cortex showed great similarity (fig. 6). There was defective formation particularly in the second and third laminæ, and wide spacing of cells was notable. The intermediate precentral convolution had suffered as little as any from the hypoplasia, showing good lamination, well-developed cells and normal glia with no fat. The occipital and hippocampal regions were intermediate between the insula and the frontal cortex in the severity of the changes. There were no inflammatory or vascular changes demonstrable in the tissue or in the meninges. Satellitosis and neuronophagia were only occasionally encountered. In looking at the cellular preparations it was surprising to find such a quiescent process, and then in the fat stains to observe such active fat release.

Summary.—A 6-year old child of dissolute parents ceased developing mentally after a supposed attack of meningitis. The head was smaller than normal on admission, and there was some motor disturbance that was not accurately described. At necropsy the pons and medulla oblongata were found to be firm and white, the alteration being due to fibrillar glia overgrowth. In addition to a poorly-developed cerebral cortex there was much fat present, both scattered in the tissue and contained in fusiform and stellate glia-cells.

Case 4.—Irene Z., Polish, 3 months old, admitted to the service of Dr. J. P. Crozer Griffith, University Hospital, Philadelphia, September 17, 1921, died October 2, 1921. Diagnosis: Microcephaly, gastro-enteritis, peritonitis. I am indebted to Dr. Griffith for permission to use the clinical notes made during my internship.

She was born naturally at full term, the second child of presumably healthy Polish parents. She was cyanosed for a prolonged period. The mother nursed the child for two months, and then started it on a very deficient milk mixture. The baby lost weight progressively, had periods of diarrhœa, cried continually, even immediately after feeding. This crying was aggravated by movement. Almost from birth it was noted that the hands were clenched and the limbs stiff. The skin was worn off the palms by the constant friction.

Examination on admission revealed a very much emaciated female child, measuring 53 cm. in length and weighing only $4\frac{3}{4}$ lb. (2,280 grm.). The head was very small, measuring 12 in. (30 cm.) in greatest circumference. The forehead was receding, with hair growing down almost to the eyebrows in fine silky lanugo. The occipital protuberance was very marked, and there seemed to be some overlapping of the parietal bones in this area. The anterior

fontanelle was wide open and somewhat depressed. The face was normally formed, but was almost constantly contorted into a spasmodic grimace accompanied by an almost inaudible cry (fig. 7). There was pronounced wasting of the sucking pads. Teeth had not yet appeared. Occasionally there was very rapid oscillatory nystagmus, mostly to the right and upward. Fibrillary tremors of the eyelids were noted. The pupils responded normally to light, although the child cried spasmodically whenever light was flashed into her eyes. Sucking movements and swallowing were carried out normally, although with interruptions.

The sternomastoid muscles were always prominent, like fibrous cords, and they projected still more during crying. The thorax was much wasted, there

FIG. 7.—Photograph of microcephalic idiot (*Case* 4) showing universal rigidity and contorted face.

being little but shrivelled elastic skin to cover the bones. The bony framework seemed normal. Heart and lungs were negative to physical examination. The abdomen was scaphoid, the rectus muscles in spasmodic contraction much of the time. The skin hung in folds. No organs or masses were palpable. There was considerable lanugo over the back.

The arms were adducted, the forearms flexed, and the thumbs clasped tightly in the palms. It was impossible to extend the fingers, and any effort at extension was met by intense resistance. Universal increase in rigidity was elicited by any sudden effort at extension, and was accompanied by the spasmodic cry. By gentle manipulation partial extension of the forearms could be obtained, but beyond a certain point the spasm would return and the arm jerk quickly back to its former position. The thumbs pointed directly

toward the hypothenar eminence, there seeming to be subluxation at the proximal joint. The skin was abraded in the palm by the constant rubbing, and by no means was it possible to extricate the thumb from its pathologic position.

The thighs were flexed and adducted, the legs also flexed, and here also the rigidity was pronounced. It was possible to support the child by the feet without the angle of flexion increasing beyond ninety degrees, and the child could be supported in board-like rigidity by the heels and occiput. Sometimes the legs were crossed. The feet were strongly incurved, the toes bent under the sole, and from here they could not be extricated. No tendon reflexes were elicitable on account of the extreme rigidity. Plantar stimulation caused no movement of the toes, but was sometimes accompanied by increased general rigidity.

Cervical and vestibular reflexes were not investigated.

During bathing the child sometimes manifested curious twitching movements of the head, associated with oscillations of the eyeballs. There were no clonic convulsions. The rigidity persisted during sleep. Only once, a few hours before death, did the rigidity give way to flaccidity, and then only for a few moments before appropriate stimulation could take effect.

Diarrhœa was persistent in spite of diet and medication, and the child became much dehydrated. A large decubitus ulcer developed over the sacrum, exposing much of the bone. Death took place after some dark brown material had been vomited.

The urine had a specific gravity of 1·005, contained a few leucocytes, but no albumin nor sugar. The blood-count revealed moderate anæmia with 15,200 leucocytes per c.mm. No Wassermann test was made.

The clinical picture in this case was one of microcephalic idiocy with intense spasmodic rigidity and frequent tonic fits.

Necropsy was performed by Dr. Morton McCutcheon twenty-two hours after death. Rigor was absent. The skull was markedly small, flattened anteriorly, with a large external occipital protuberance. The heart and mediastinal structures were normal. The lungs showed small areas of catarrhal pneumonia. The intestinal coils and spleen were partly covered by a fibrinopurulent exudate, in which Gram-positive diplococci were demonstrable by smear. The suprarenals appeared very thin; the colon showed moderate catarrhal inflammation. Culture of the heart blood and peritoneal exudate gave a heavy growth of *Bacillus coli*. Microscopically the gross findings were established.

The brain weighed 110 grm. It was small, especially in the frontal regions. The convolutions were broad in this area and the fissures shallow. The pallium was very soft. In contrast to the cerebral hemispheres the cerebral peduncles, pons, medulla, and upper spinal cord were firm to the touch and retained their shape when cut across. The internal structure of these parts could readily be distinguished and appeared normal. Even after fixation in formalin this difference in consistency could be appreciated on palpation, and

on section it was found to extend to the basal ganglia, although the subcortical white matter seemed to have escaped. The spinal cord was probably somewhat smaller than normal, and showed no increased firmness except at the cephalic extremity.

Histological sections of the cord were considerably distorted, due to the softness of the tissue. The dorsal horns were large. Rather deep fissures were seen at the periphery. The central canal was open, sometimes rounded, sometimes slit-like, and it showed a large, pale, acellular area around it. The gray matter aside from this appeared fairly normal. The white matter was less than normal in amount, and the pyramidal tracts were not developed. Glia stains were unsatisfactory, possibly on account of the period between death and necropsy. Fat stains revealed nothing in the spinal cord. The ventral horn-cells were normal in shape and showed slight fragmentation of chromatin. The nerve-roots appeared normal. The peripheral portion of the cord showed very marked vacuolization, interpreted as a manifestation of shrinkage rather than œdema.

In contrast to the cord, cerebellum and cerebral cortex, all of which showed marked shrinkage, the medulla oblongata maintained its internal form in a remarkable manner. The architecture was altogether normal. The cranial nerve nuclei were easily recognizable, their cells normal for the infant; the olivary nuclei were quite prominent, and the many afferent pathways could be recognized without difficulty. The tissue appeared compact, even in thin paraffin sections. The floor of the fourth ventricle was flat and smooth, the ependymal cells high and occasionally retaining their cilia. Beneath the ependyma there was a clear, relatively acellular stratum which showed very numerous glia fibres forming a dense feltwork. In the lateral recesses of the ventricle there was marked heaping up of the ependyma in some places with invagination in others. Gland-like spaces were occasionally formed. Weigert preparations showed practically normal myelinization of all tracts except the pyramidal, which could not be expected at this time of life. Fat stains gave no evidence of a disintegrative process.

The cerebellum showed marked retraction of the granule layer from the molecular. There was also partial persistence of the external granule layer, probably a normal manifestation in this young infant. The molecular layer was in general rather thin, the Purkinje cells reduced in number and sometimes apparently dislocated upward into the molecular layer. In some places the tissue resembled the atrophic leaflets consequent upon infarction. The underlying granule layer in these places was atrophic. There was little fibrillar gliosis however, although large rounded glia-cells were found in considerable numbers in the white matter. The blood-vessels were normal, having no cellular collections about them. The dentate nucleus appeared normal; likewise the choroid plexus. Fat stains and Weigert preparations revealed no outstanding defects. There was moderate increase of neuroglia fibres in the roof of the fourth ventricle.

The pons again showed normal architecture of marked compactness, all

structures appearing normal except for the unmyelinated pyramidal tracts and ponto-cerebellar fibres. The floor of the ventricle and the sides showed the same characteristics as in the medulla, palisade ependyma interrupted laterally by buds and rosettes separated from the ventricular cavity. The cells of the locus cœruleus contained no pigment. Fat was absent. Glia fibres were abundant, but with inconsiderable increase in the number of glia nuclei. No particularly large glia-cells were met with.

The peduncles showed compact tissue with normal architecture. The aqueduct was narrowed by bulging masses of subependymal glia overgrowth covered with a single layer of ciliated columnar ependymal epithelium. Sometimes these cells were heaped up into several strata. The subependymal layer

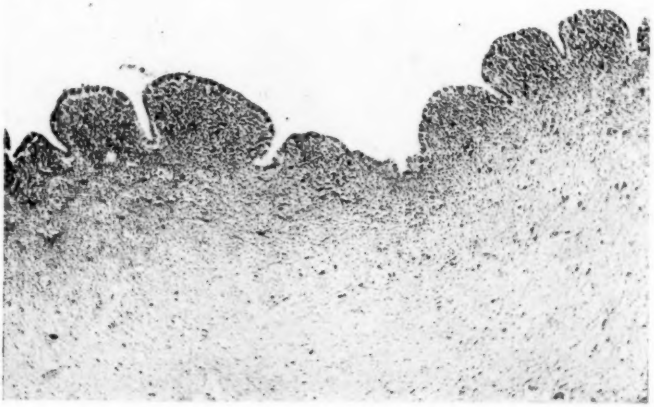

FIG. 8.—Thalamus of *Case* 4. Papillary projections of the ependyma lining the third ventricle due to neuroglia fibre excess.

did not appear fibrous, but rather homogeneous in ordinary cell preparations, but its fibrillar nature was made manifest by proper staining. At a short distance from the ependyma there was a well-defined stratum of glia-cells with abundant cytoplasm arranged in a direction perpendicular to the ependymal surface. This somewhat resembled the stratum of spongioblasts found in embryonic preparations. The floor of the aqueduct was narrowed to a fissure, and at the bottom some of the ependymal cells were separated from the ventricle and assumed a rosette shape. The cells of the locus niger were unpigmented, otherwise these cells presented a normal appearance. Fat was absent. The pyramidal tracts were rather small and incompletely myelinated. The meninges and vessels were normal. There were no signs of inflammation. Some atypical nerve-cells were encountered in the oculomotor nucleus.

The thalamus and corpus striatum revealed an entirely different picture from those seen at lower levels. Throughout the brain-stem glia overgrowth was the only important finding. Above this level, fatty changes became manifest. The thalamus was of normal size; the ganglion cells were present in apparently normal numbers, but many of them had undergone acute and chronic changes. Satellitosis was very marked; a few very black cells in the H. and E. preparations were interpreted as being calcified. The tissue showed the effects of considerable shrinkage with much vacuolization. The neuroglia was proportionately increased. Large branched forms were easily visualized, even without special stains. The gliosis beneath the ependyma heaped this

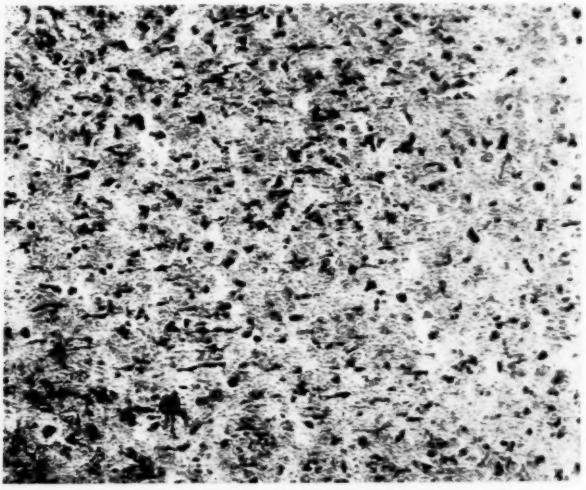

FIG. 9.—Caudate nucleus of *Case* 4. Herxheimer stain. A multitude of microglia cells silhouetted by their content of fat globules.

membrane up into projections suggesting granular ependymitis, but there was no hiatus in the ependyma and no sign of inflammation (fig. 8). Fat stains revealed an extraordinary number of fine and coarse reddish globules scattered through the various centres (fig. 9). They were most numerous in the external and ventral nuclei of the thalamus. These globules were enclosed within microglia-cells, but had not ballooned them out to any considerable degree, with the exception of a few that lay near the vessels. As a general rule these phagocytic glia-cells were spindle-shaped, but sometimes multipolar, and in many instances they were silhouetted by the fat contained within them (fig. 10). They were so large in some instances that it was thought that these might be ganglion cells undergoing a peculiar fatty metamorphosis. Closer examination, however, revealed their true character. A small amount of fat

was found in the vicinity of the blood-vessels, not like the appearance of a gross destructive lesion, however. Pigment was abundant in the same locations, also within the cytoplasm of phagocytic cells. Small globules of fat and pigment could be found lying in the tissue and not enclosed in microglia cells. There was a certain amount of fibrous glia overgrowth, but it did not compare with the gliosis at lower levels.

In the putamen and caudate nucleus there were found here and there small groups of large and small glia nuclei with very little interstitial tissue, resemb-

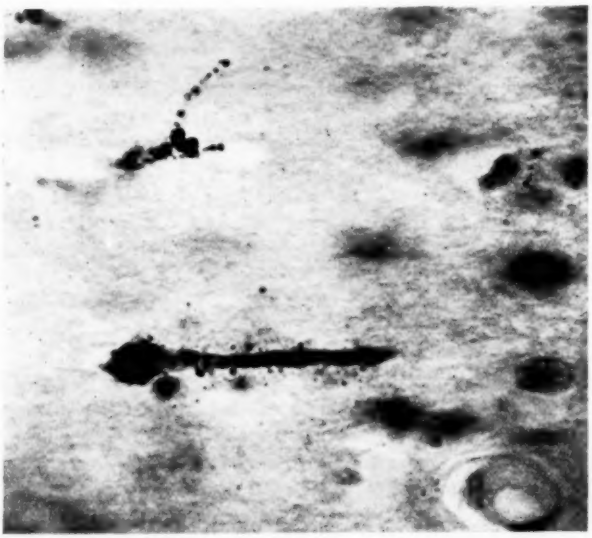

FIG. 10.—High-power view of two microglia cells from caudate nucleus of *Case* 4. The nucleus is not invaded.

ling the glia rosettes sometimes found in certain degenerative and inflammatory conditions. Fat was particularly abundant in these areas. No actual giant cells were found, however. Beneath the ciliated ependyma covering the caudate nucleus there was considerable overgrowth of fibrous neuroglia, together with the presence of a variable number of glia-cells with large vesicular nuclei that were sometimes sufficiently densely packed to resemble gliomatous tissue. There were no mitoses observed, however. The nerve-cells appeared to be undisturbed except for the presence of acute degenerative changes. Here again fat stains revealed a very large number of microglia cells, fusiform or multipolar, their protoplasmic projections outlined in red due to the very large number of minute fat globules contained within them. The neurons themselves did not contain fat or any trace of pigment.

The globus pallidus presented an entirely normal appearance. The internal

capsule showed but little myelinization; the knee was altogether pale. The whole of the cerebral tissue was rather loose in texture.

The cerebral cortex was rather thin and undeveloped, but not abnormally so for an individual three months of age. The cells were quite numerous and took the stain normally. There was an increase in the protoplasmic and fibrous neuroglia, however, which gave to the cortex an appearance of increased density. The cytoplasm of these cells could be seen rather plainly, even in the H. and E. stain.

There were no giant forms. They were not limited to the cortex, but large vesicular nuclei were found rather frequently in the underlying white matter. In preparations with Scarlet it was seen that fat was practically limited to the cortex, there being only a few compound granule cells collected about the vessels in the white matter immediately subjacent. This fat was probably carried there from the cortex by the wandering cells. Here again the fat was usually enclosed in fusiform or multipolar microglia cells which sometimes reached large size but never contained more than one nucleus. The nucleus, moreover, was not invaded by the fat. In the hippocampus this fatty alteration reached its maximum. Here the fat practically displaced the ganglion cells from view when the special stain was used, but in cell preparations there was only a moderate reduction in the thickness of the layers, and an abnormal number of vesicular and irregular glia nuclei. If there was a reduction in the number of nervous elements it was so slight as to be inappreciable. The layers in the cornu ammonis could be made out distinctly. With this great increase in the amount of fat present, there was also an abundance of crystalline material in sheaves and plates, probably cholesterol. This showed up plainly with the crossed Nicol prisms, being strongly birefringent. These crystalline deposits did not seem to be enclosed in cells, and were as numerous as those seen about any fresh infarct. The amount of fat present was out of all proportion to the derangement in architecture. Myelin sheath preparations showed complete absence of medullary substance in the cortex, and much of the tissue immediately beneath the cortex was pale, but in the white matter there was no wholesale breaking down of the myelin sheaths with enormous numbers of compound granule cells, such as is described in Schilder's disease. Rather the myelin sheaths were undeveloped. In the frontal region the lamination was simple, and there seemed to be more of a tendency for the ganglion cells to be arranged in primitive fashion in strands perpendicular to the surface than in strata.

Neither in the meninges nor in the nervous parenchyma was there any suggestion of inflammatory changes. The blood-vessels appeared quite normal.

Summary.—A microcephalic idiot, aged 3 months, showed intense spastic rigidity with abolished reflexes and irreducible contractures. Tonic fits followed every kind of stimulus. The child died of enterocolitis and terminal peritonitis. On examination, it was found that the whole brain-stem, although retaining its normal architecture, was

greatly overgrown by fibrous neuroglia, making its firmness a matter of comment in the fresh state. Above the brain-stem there was diffuse fatty degeneration in the gray matter without implication of the white matter, and enormous numbers of microglia cells had picked up the fat released.

Comment.

The pathologic processes in these four cases were of great similarity, though of varying extent. They presented two main features, the hypergliosis of fibrillar type in the brain-stem and spinal cord, and the diffuse fatty alteration with phagocytosis at higher levels, especially in the cerebral cortex and basal ganglia, although to some extent in the thalamus. The underlying disease was revealed scarcely at all in cell stains or in myelin sheath preparations. This fact probably accounts for the description of normal anatomic findings which are reported by almost all of those authors mentioned who have described similar cases of the disease.

The relationship of this form of diffuse gliosis of the brain to the universal diffuse gliosis seems to be close, yet in the latter cases we more often meet with brains larger than normal, whereas in those presented in this study the brains, except for the third, have been distinctly undersized. This particular brain was the least diffusely affected of the four. The normal Weigert pictures would differentiate the affection from Schilder's disease, even if no search were made for the large phagocytic glia-cells that abound in the white matter in this affection.

From the histologic point of view, there seemed to be more evidence favouring a disordered metabolism than a destructive or disintegrative process. The condition of the cells and myelin sheaths gave no hint of the large deposit of fat that could be found by appropriate staining. The fact that fat was abundant in the areas not affected by the fibrillar gliosis, and all but absent from the areas of intense gliosis, would suggest that, since the gliosis affected lower levels, there had been a metamorphosis progressing from below upward, manifesting itself first as a fatty change, then exciting glia reaction, with later laying down of enormous numbers of glia fibrils. Yet the presence in the spinal cord of a widely patent central canal with a large *couche fibrillaire* about it was not in keeping with this hypothesis. Moreover, the immature type of cortical architecture, and the immature type of cells present, would tend to place the defect rather in the early period of development than later in the course of existence. The whole pathogenesis of diffuse gliosis is very much of a mystery, and its presence in certain phylogenetically older

centres, with evidences of disordered metabolism at higher levels, would tend to throw the explanation into the realms of cerebral chemistry and its disorders, a field where speculation plays a more dominant rôle than demonstration.

The remote predisposing causes are no more clear than the term "degenerate," which was applied to the parents of these children. Syphilis in the parents was known in two instances, but the histologic alterations were not syphilitic. Rolly's twins at the fourteenth pregnancy seem to be the only cases in a large family. Illegitimacy is rather prominent in the ancestral histories.

Manifestations of the disease are present at birth or shortly afterward. Births are natural and easy because of the small heads. Development is deficient and retarded; convulsions are often noted in the early weeks of life. The patients remain permanently retarded, and may even regress in their accomplishments, a clinical picture quite common to all the diffuse scleroses. Motor disturbances, especially rigidity with suppressed reflexes, are seen in the late stages of the diffuse glioses. The early onset and intense character may be due to the presence of the pathologic alteration at the low levels.

It is a question whether the rigidity manifested in these cases belongs to the pyramidal system or not. The Babinski reflex has been negative, even in those young patients in whom it could normally be expected. The posture has not been altogether that of decerebrate rigidity, *sensu strictiore*, yet it has certain features in common with it. It was unfortunate that the clinical importance of the cervical reflexes was not recognized at the time that these patients were examined. If there were decerebrate rigidity present, one would have to conceive at least of a physiological separation of the mesencephalic centres, let us say, from the lower ones. It is true that in some of the cases the gliosis practically ceased above the level of the corpora quadrigemina, but here again the fibre tracts below this level appeared normal. There were no paralyses of the peripheral type, even in spite of the extreme gliosis present in the medulla oblongata and spinal cord. The gliosis at the base may be considered to have been a preservative action, sustaining the cells and fibres in their functional activity, yet in this case it would be difficult to explain how the normal parts of the cord, e.g., the thoracic region of the third case, could carry on their functions. It may be that the disordered nervous metabolism so evident at higher levels in the fat release may have occasioned a more or less global reduction in the inhibitory effect of the higher centres upon the lower ones. The process

undoubtedly was more severe in the individuals dying young and presenting the most intense muscular rigidity. The whole question must be left open for further investigations of these cases in greater detail from the standpoint of pathological physiology in the clinic and of pathological chemistry of the brains. This paper will have accomplished its purpose if it calls attention to this variety of diffuse gliosis of the lower parts of the brain associated with perverted fat metabolism at higher levels.

SUMMARY.

Four cases of considerable clinical and great pathological similarity are described. Microcephaly, generalized muscular rigidity with tonic fits and a peculiar, almost noiseless cry, and severe idiocy, are the outstanding clinical peculiarities.

Pathologically, there is found enormous diffuse fibrillar gliosis of parts of the spinal cord, medulla oblongata, pons and mesencephalon, sometimes involving also the basal ganglia. Aside from this there is little structural alteration at these levels. The cortex and basal ganglia give evidence of defective development from a cytological and architectural point of view. Disordered fat metabolism is a distinctive feature. Even though the cells and myelin sheaths appear relatively normal, there is a large amount of fat scattered dust-like through the gray matter, both within cells and outside, and the collection of small masses of this fat in ordinary compound granule cells about the walls of vessels. The absence of inflammatory, vascular, and well-known degenerative changes is a striking feature.

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A STUDY OF THE ELECTRICAL SKIN RESISTANCE AND THE PSYCHOGALVANIC REFLEX IN A CASE OF UNILATERAL SWEATING.

By CURT P. RICHTER.

Psychobiological Laboratory, Phipps Psychiatric Clinic, Johns Hopkins Medical School.

On March 1, 1924, Mr. A., aged 47, entered the Johns Hopkins Hospital. For a year he had been suffering from periodic attacks of excruciating pain in the left arm and upper part of the left chest. He stated that on hot days he sweated only on the right side, the left hand and arm and the left side of the face remaining quite dry. In the clinical examination it was found that the left eye showed a definite enophthalamus, ptosis, and contracted pupil, and that the temperature of the skin in the affected area was noticeably increased. A swelling was detected on the left side of the neck large enough to push the trachea well over to the right. Voluntary motor power in the left arm was not impaired except during the attacks, when the pain was too severe to permit movement of the arm.

The impression of this case was that a tumorous growth in the neck had completely severed the left sympathetic chain near the level of the third thoracic vertebra, thus producing the eye and skin changes, and that the pain was caused by the pressure of this growth on the brachial plexus.

For some time previous to March, 1924, we had been studying certain electrophysiological manifestations which seemed dependent ultimately on the function of the autonomic nervous system — particularly the psychogalvanic reflex and the electrical resistance of the body. We had been interested in what controlled the psychogalvanic reflex, since the question as to whether it depended on sweat glands or capillaries was still unsettled, but we had been unable to demonstrate any relationship which might solve the problem. In the matter of electrical resistance, on the other hand, we had found that the resistance offered by the body to the passage of a delicate constant current is localized almost entirely in the skin. This is shown quite conclusively by the fact that a minute puncture through the skin causes

the resistance to drop from any level, however high, practically to zero [4]. And there was further evidence which seemed to indicate that the resistance of the skin bears a definite relation to the action of the sweat glands inasmuch as the resistance was found to decrease always with sweating. It seemed desirable, however, to obtain more information regarding this relationship.

It occurred to us that a case of unilateral sweating, which is not uncommon, might throw further light on the significance of the sweat glands for these electrophysiological manifestations. Through the kindness of Dr. Frank R. Ford, of the Neurological Department of the Johns Hopkins Hospital, we were able to study the case cited above with regard to both psychogalvanic reflex and skin resistance. A patient of this kind, with normal functioning of sweat glands on one side of the body and a complete absence of their activity on the other, would offer an opportunity for comparing step by step, under exactly the same conditions, the resistance readings on each side and the psychogalvanic reflex from each side. The investigation, we feel, has contributed some conclusive data to these two problems.

Thus, in the following experiments, the psychogalvanic reflex was recorded from each hand under normal conditions, and also at the height of the sweating reaction produced by a hot-air bath, or by pilocarpine injection. The skin resistance was measured from the two hands at intervals extending over a period of almost three months, and the changes in resistance produced by the hot-air bath and by hypodermic injections of pilocarpine, atropine, and adrenalin were measured. At the same time observations were made of the sweating reaction on the two sides of the body and the exact area of skin involved by the lesion was determined.

Methods.

Essentially the same methods were applied in the studies of both the psychogalvanic reflex and the electrical resistance. Four electrodes were used, one attached to the palm and one to the back of each hand, in the manner shown in fig. 1. The electrodes consisted of hemispherical pieces of zinc $1\frac{1}{4}$ in. in diameter, with brass rods screwed into the top to serve as handles. The flat surface of the zinc was smoothly polished and covered with a paste made of kaolin and saturated zinc sulphate solution. These electrodes are practically non-polarizable, they make an intimate moist contact with the skin without producing irritation or injury, and they are very simply and easily prepared.

The records were taken on a string galvanometer of the type employed in electrocardiographic stations (Hindle).

In the psychogalvanic experiments no external current was intro-

FIG. 1.—Photograph showing method of attaching electrodes.

duced. Our investigations were limited to the so-called E.M.F., or electro-motive-force method, whereby we recorded the changes in potential produced between the two electrodes by emotional stimuli. The string was standardized so that 10 m.v. produced a deflection of

2·5 cm. on the scale, and the deflections were registered photographically on bromide paper. The stimuli employed in eliciting the psychogalvanic responses were pin-pricks, auto-klaxon horns, threats, and shots from a 0·32 cal. pistol. The pistol shots were found to be most satisfactory, because these stimuli can be kept absolutely constant in every respect, and the incidence of the stimulus is very short, and can be accurately recorded. This is important for the study of the latency period of the responses.

In the second series of experiments, the resistance offered to the passage of a very minute constant galvanic current through the body was measured. It may be mentioned here that resistance determined in this way is the apparent, not the true resistance. Apparent resistance is much higher than true resistance, the difference being due to polarization phenomena produced in the skin as the current passes through it. Biologically the polarization effect and the apparent resistance are far more important than the true resistance, which can be measured only with alternating currents of very high frequency. By using four electrodes, one attached to the palm and one to the back of each hand, it is possible to pass the current through the body in six different ways, so that six different resistance readings are obtained :—

From the back of the right hand to the palm of the right = R_1
From the back of the left hand to the palm of the left = R_2
From the back of the right hand to the back of the left = R_3
From the palm of the right hand to the palm of the left = R_4
From the back of the right hand to the palm of the left = R_5
From the palm of the right hand to the back of the left = R_6

Now if the skin resistance of the palm and back of each hand is represented in the following way :—

a = Resistance of right back.
b = Resistance of right palm.
c = Resistance of left palm.
d = Resistance of left back.

Then :—

$$a + b = R_1$$
$$c + d = R_2$$
$$a + d = R_3$$
$$b + c = R_4$$
$$a + c = R_5$$
$$b + d = R_6$$

We have then six equations with four unknowns. From these

readings the resistance of the skin beneath each electrode can be calculated algebraically. It is important that this determination be made because we have found that the skin of the palm and back of the hands often responds very differently so far as electrical resistance is concerned.

The hot-air bath used in the sweating experiments consisted of a framework of wooden laths, 5 ft. in length and semi-cylindrical in shape. The framework was placed over the patient as he lay in bed, and covered with heavy woollen blankets, so arranged that any part of the body could be quickly and easily examined for the presence of sweat. The heat was provided by ten carbon lamps attached to the laths inside the bath. The arm-rests and the hands were kept inside and shielded from the direct heat rays of the lamps with pieces of opaque paper.

Pilocarpine, atropine, and adrenalin were injected subcutaneously into the upper arm in order to avoid any local effects on the hands, since the subsequent readings were to be taken from them. The doses used were as follows: pilocarpine 1/5 gr., atropine 1/50 or 1/100 gr., and 1 c.c. of adrenalin 1 : 10,000.

Results.

Psychogalvanic Reflex.

(1) *Absent on injured side.*—The records of fig. 2 show that the psychogalvanic reflex was absent on the injured left side. The stimulus used in these records was a shot from a 0·32 cal. pistol, fired about 6 ft. behind the patient. All other stimuli, pin-pricks and the klaxon horn, likewise failed to elicit any response in the left side, whereas they regularly produced a response on the normal side.

(2) *Differentiation of quick and slow phases.*—The fact that the left hand of the patient was completely inactive so far as the psychogalvanic reflex was concerned offered a unique opportunity for determining what part of this response is produced by the palm and what part by the back of the hand. Ordinarily the record is a resultant of the electrical changes under both electrodes. In this case, however, when one electrode is attached to the side which gives no response, the deflections obtained must be produced by that part of the skin with which the other electrode is in contact. In other words, the electrode on the left side serves as a "dead" lead such as is used in recording monophasic action currents from nerves and muscles. When the

other electrode is attached first to the back and then to the palm of the right hand, very definite differences appear in the psychogalvanic responses (see fig. 3). With it attached to the back of the right hand

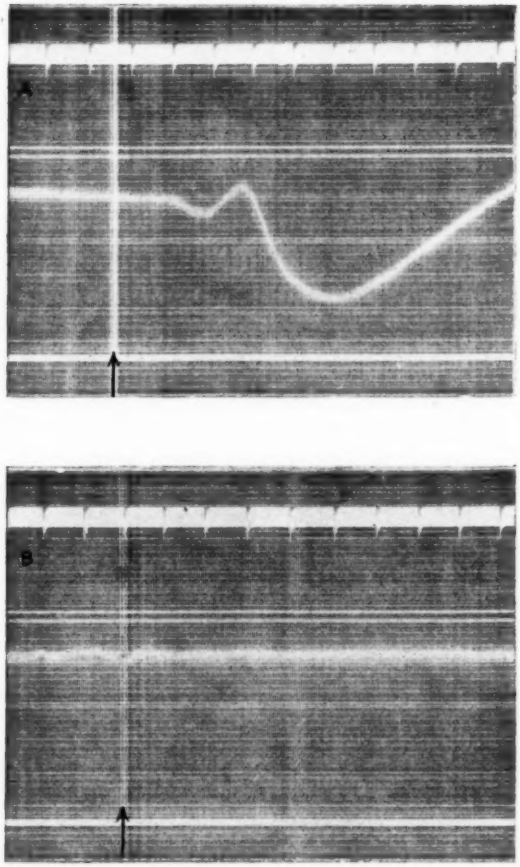

FIG. 2.—Records showing psychogalvanic reflex response to pistol shot. A = normal right side, and B = injured left side. The electrodes were attached to the palm and back of each hand and no external current was used. The string was loosened so that 10 m.v. would give a 25 mm. deflection on the record. Time is indicated in seconds. The pistol shot is indicated by a white line running directly across the record.

a slow prolonged deflection occurs after a latency period of about four seconds (see fig. 3, A and B). When it is in contact with the palm, a quick phase, occurring after the usual latency period of about one

second, is recorded, in addition to the slow prolonged phase (see fig. 3, C and D). Fig. 3, E and F, shows records of the psychogalvanic reflex on the left and right hand just after the above records were taken,

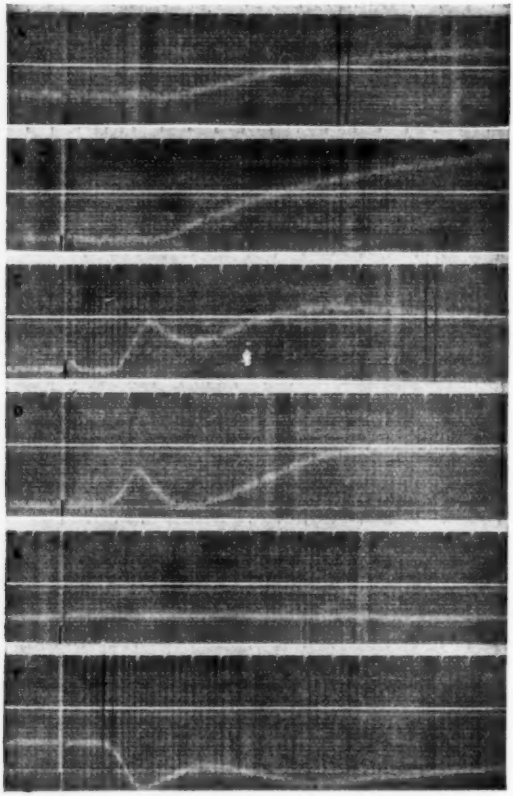

FIG. 3.—Psychogalvanic reflex responses when the galvanometer was connected with the—A. Back of right hand and back of left. B. Back of right hand and palm of left. C. Palm of right hand and back of feft. D. Palm of right hand and palm of left. E. Left hand, palm to back. F. Right hand, palm to back. The stimulus, a pistol shot, is indicated by a small black line.

E shows the absence of the reflex on the left side, and F shows the presence of both the quick and slow phase on the right side.

These experiments demonstrate that the quick phase of the psychogalvanic reflex with the one-second latency period is produced by the

palm of the hand, and that the slow prolonged phase with the four-second latency period is produced on both the palm and back of the hand. Because sweat glands are much more copious on the palms than on the backs of the hands, these results suggest that the quick phase is produced by the sweat-glands and the slow phase by some other mechanism.

This conclusion has been justified by records taken on a patient suffering from total absence of sweat-glands (ichthyosis—established by extensive histological examinations of excised skin, made by Dr. Gilchrist, of the Department of Dermatology of the Johns Hopkins Hospital) (see fig. 4). The records, repeated many times on different

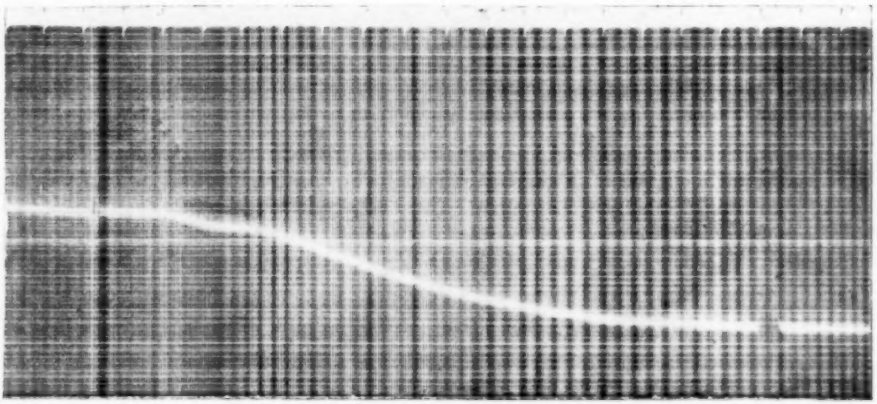

FIG. 4.—Psychogalvanic response to pistol shot in patient suffering from congenital absence of sweat-glands (ichthyosis).

days, showed consistently that the quick phase was always absent while the slow phase was clearly present.

Dr. E. B. Carrier made a further investigation of the capillaries of this patient. Observations at the same time of the psychogalvanic reflex showed that an increase in the number of visible open capillaries in the skin occurred simultaneously with the deflection of the galvanometer string. This finding suggests that the slow phase may be produced by the capillaries. This cannot be definitely concluded, however, without further evidence, since these phenomena may occur simultaneously but still quite independently. Furthermore, we have found in other work that the capillaries seem to have no effect at all on

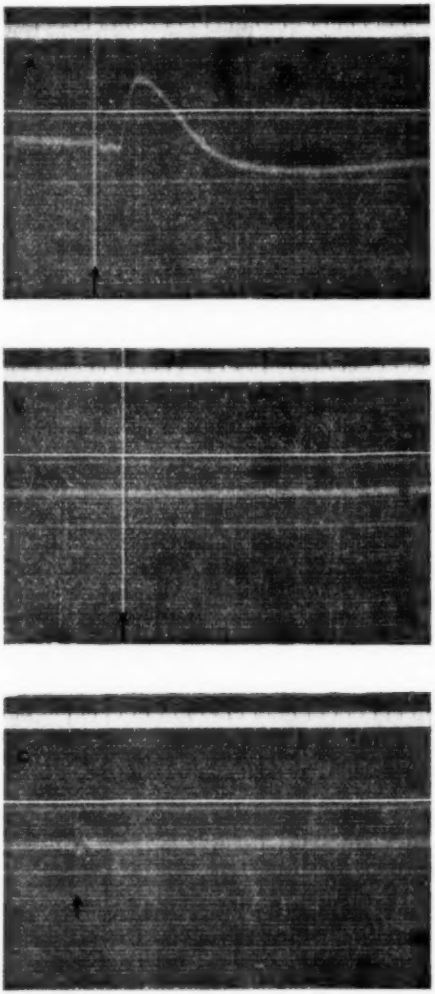

FIG. 6.—Records of the psychogalvanic reflex responses after pilocarpine injection. A shows the response that was obtained from the normal side by a pistol shot. The spontaneous fluctuations present after the sweat-bath are entirely lacking. B shows the absence of both the psychogalvanic reflex and the spontaneous waves on the injured side. C shows the absence of the psychogalvanic response on the normal side also, after the stimulus had been repeated only a few times. The auto-klaxon horn was used in this record, but the same results were obtained when the pistol-shot stimulus was given.

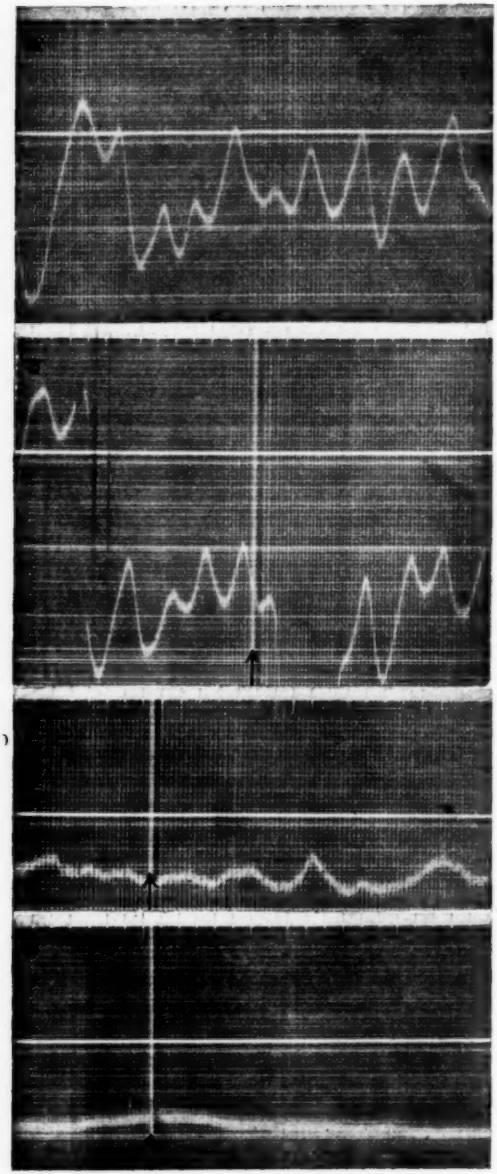

FIG. 5.—Psychogalvanic reflex response at height of sweating reaction produced in the hot-air sweat-bath. A. Right hand. B. Right hand; spontaneous fluctuations and psychogalvanic reflex response. Pistol shot. C. Back of right hand to back of left. Pistol shot. D. Left hand. Pistol shot.

who showed that the psychogalvanic response can be obtained by stimulating the sympathetic chain, and that the response disappears after the chain is cut [2]. We have confirmed their results in this laboratory in experiments on cats, in which removal of the stellate ganglion eliminated both the spontaneous fluctuations and responses to individual stimuli.

Electrical Resistance.

(1) *Higher on side of lesion.*—It was found that the electrical resistance is higher on the injured side. The average of eight readings taken

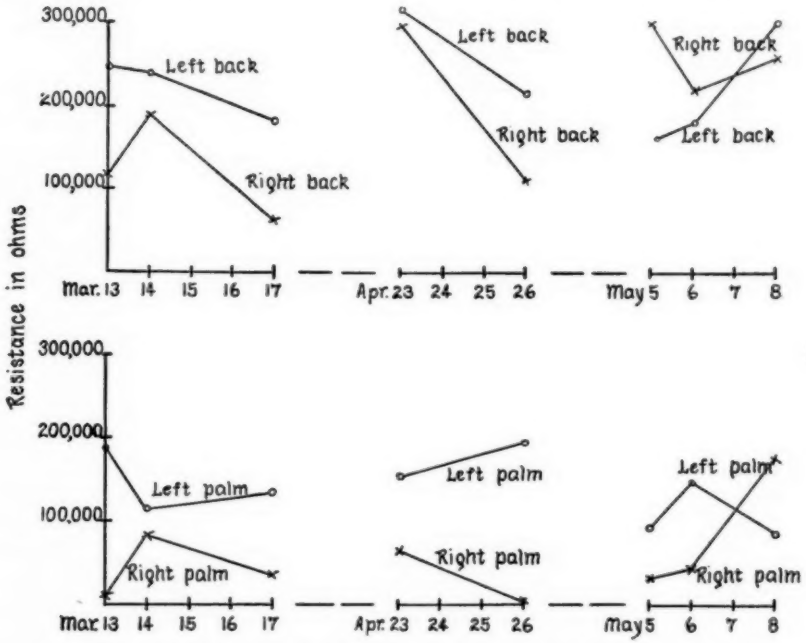

FIG. 7.—Records showing electrical resistance of the skin of the palm and back of the hands on eight different days over a period of two months. The resistance is given in ohms on the ordinates, and the days of the experiment are given on the abscissæ.

during three months was 139,000 ohms for the left palm, and 55,000 ohms for the right palm, 231,000 ohms for the left back, and 195,000 for the right back. The individual readings are shown in fig. 7.

(2) *Effect of sweating produced by hot-air bath.*—The differences between the two sides were brought out very strikingly in the sweat-bath

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the electrical resistance of the body, that the non-sweat-gland changes in resistance can be explained best on the basis of changes in the epithelial cells in the skin. We must keep in mind, then, the possibility that the epithelial cells may contribute to the production of the slow phase of the psychogalvanic reflex.

(3) *Effect of sweating produced by hot-air bath.*—The differences in the psychogalvanic responses from the two sides were brought out very distinctly when the patient with unilateral sweating was placed in a hot-air bath. Profuse sweating and very large psychogalvanic responses occurred on the normal side; the side of the lesion, on the contrary, remained quite dry, and the psychogalvanic response was still absent (see fig. 5). And in this experiment, in addition to the usual clear-cut responses to specific stimuli, there were many spontaneous fluctuations set up under the electrode on the right side, and none whatever on the left. Again, using the left side as a dead lead, we found that these fluctuations have their origin exclusively on the palm of the hand, and occur at a fairly regular frequency of 22 per minute. It is possible that further study of this rhythm may throw some light on the frequency of the impulses coming down from the heat centres in the brain and spinal cord.

(4) *Effect of sweating produced by pilocarpine.*—Hypodermic injections of pilocarpine gave very different results. Contrary to the hot-air bath experiment, it was found that after the pilocarpine injection the injured side sweated sooner and more profusely than the normal side. That the psychogalvanic reflex, however, was still lacking on the injured side may be seen in fig. 6 B. It was present at the beginning on the normal side (fig. 6 A), but disappeared when the stimulus had been repeated only a few times (see fig. 6 C). And the spontaneous waves which were so conspicuous at the height of the sweating response produced by hot air were never present here on either side.

(5) *Summary.*—The results presented, so far, on the psychogalvan.c reflex, then, indicate that it is made up of two parts, the quick response occurring from one to two seconds after the stimulus, and the slower and more prolonged changes occurring four to eight seconds after the stimulus; the former dependent on the sweat-glands, the latter on either the capillaries or the epithelial cells. Furthermore, we may conclude that both the quick and the slow components are produced through impulses arriving from the sympathetic nervous system, since, on the side of the sympathetic lesion, the responses were entirely lacking. This is in agreement with the work of Schilf and Schuberth,

experiment mentioned above. The record obtained from this experiment is shown in fig. 8. In it the resistance is presented separately for the palm and back of each hand. The resistance in ohms is given on the ordinates, and the time on the abscissæ. The patient was placed in the bath at 10.50, without the heat turned on, and the first reading was taken at 11 a.m. At that time the resistance of the back of each hand was about 190,000 ohms, and of each palm 130,000 ohms. All showed a gradual but steady decrease until some time after the heat of the

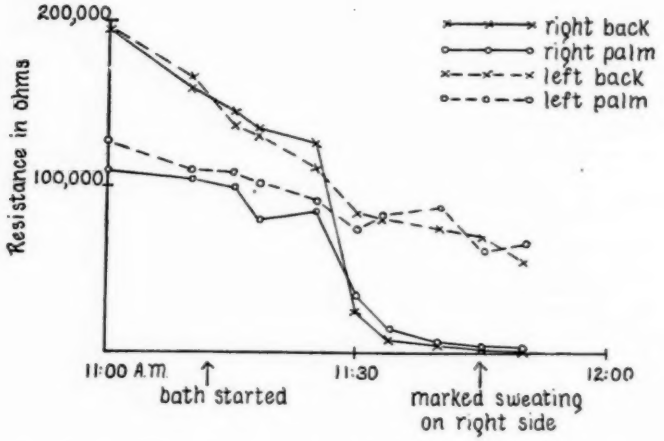

FIG. 8.—Records of resistance changes produced during hot-air sweat-bath. Resistance is given in ohms on the ordinates, and the time of the experiment is given on the abscissæ.

bath was turned on at 11.12. At 11.30 both the palm and back of the normal right hand showed a sudden marked drop to 50,000 ohms, and then, in the next few minutes, almost to zero. This phenomenon preceded the appearance of profuse sweat all over the right side by several minutes. During this time the left hand showed only a slight decrease in resistance on palm and back alike, and no sweating whatsoever, although the skin was very hot. At the end of the experiment, the resistance of both the palm and back of the left hand was still over 50,000 ohms, while that of the palm and back of the right hand had dropped to zero.

During this experiment we were able to map out exactly the area of the body which was affected by the lesion. The left side of the face and head, the upper part of the chest, and the entire left arm remained

perfectly dry, although the rest of the body was covered with sweat (see fig. 9).

(3) *Effect of sweating produced by pilocarpine.*—The effect produced on the resistance by pilocarpine is shown in fig. 10. The palm and

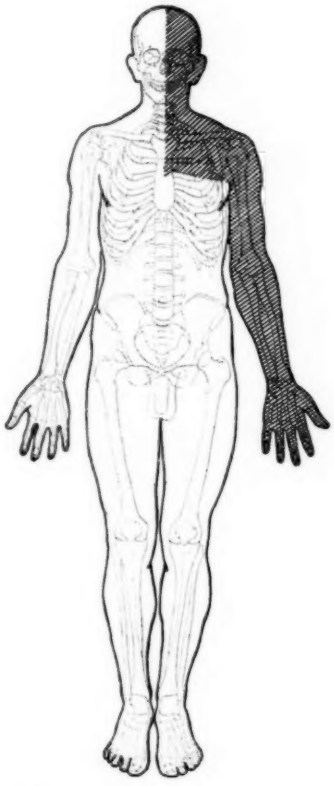

FIG. 9.—Chart showing area affected by the lesion, as determined by the sweat-bath experiment. The shaded area remained perfectly dry throughout the experiment, when all the rest of the body was covered with sweat.

back of each hand are presented separately just as before. At 10.30 a.m. before the injection, the resistance of the right palm was 50,000 ohms, while that of the left was 140,000 ohms; the resistance on the back of each hand was approximately 200,000 ohms. The pilocarpine was injected at 10.46 and the next reading taken at 10.47. The absence of

any immediate change in resistance demonstrated that the injection of itself had no effect on the resistance in this experiment, although it does sometimes have a very great effect. At 10.53 the resistance of both

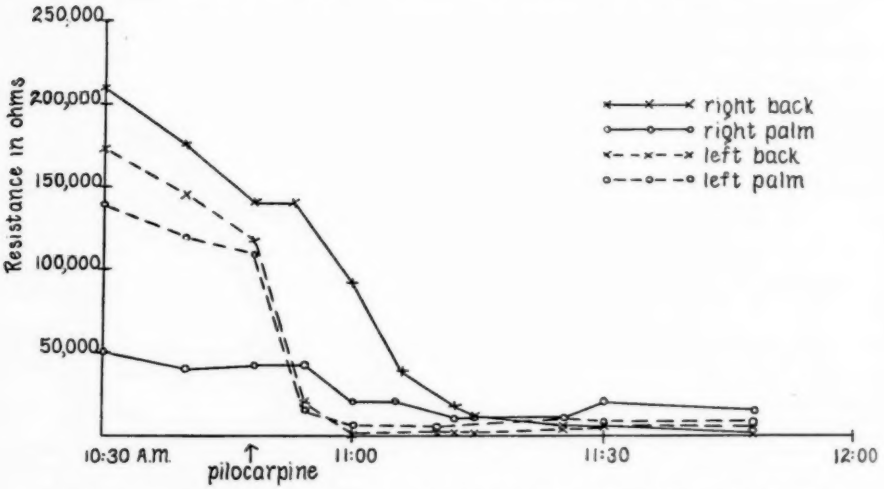

FIG. 10.—Records showing the effect of injection of $\frac{1}{4}$ grain of pilocarpine on the electrical resistance of the palm and back of each hand.

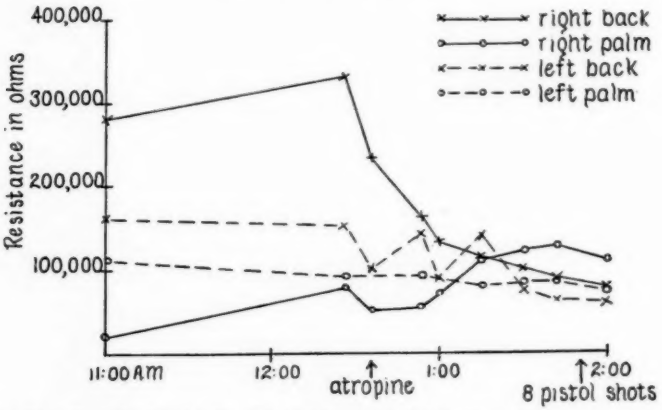

FIG. 11.—Records showing the effect of hypodermic injection of atropine $\frac{1}{50}$ grain.

palm and back of the left side had dropped to 30,000 ohms. By 11.00 a.m. it was zero on the back and less than 10,000 ohms on the palm. Three minutes later the left arm and hand, and the left side of

chest and face became covered with moisture. The resistance of the back and palm of the right hand, on the contrary, dropped very gradually and did not reach the low level of 10,000 ohms until 11.13, fully thirteen minutes after the left hand. Shortly afterwards, the right side also became covered with moisture.

This experiment, then, gave results directly contrary to those obtained with the sweat-bath. Whereas in the sweat-bath experiment, the injured side failed to show sweat and a decrease in resistance, in the pilocarpine experiment it responded with a large decrease in resistance and moisture long before the normal side showed such changes. Moreover, the drop in resistance was more rapid on the back than on the palm of the hand.

We wish to call attention at this point to the fact that in this experiment, as well as in the sweat-bath experiment, the drop in resistance preceded the appearance of moisture by at least three to six minutes. It is possible, then, in this way to register the increase in permeability which takes place when the sweat glands are innervated before the sweat becomes visible on the surface of the skin.

(4) *Effect of atropine.*—In order to study further the resistance of the two sides, atropine was injected. We know that this drug inhibits sweating and also that it usually produces an increase in the resistance of the palm of the hand, while the back either shows a decrease or else remains absolutely unaffected. In the experiment recorded in fig. 11, both the palm and back of the left hand were essentially unaffected by the atropine. The increase in the resistance of the right palm was not as great as usual, and the back of the right hand showed a large decrease a few seconds after the injection was made. This probably was due, in part at least, to the pain of the injection rather than to the effect of the atropine itself.

At the height of the atropine reaction, the psychogalvanic reflex was present but small on the right side, and absent on the left.

(4) *Effect of adrenalin.*—Adrenalin was likewise injected on two different occasions, but each time the pain and discomfort produced in the arm and chest were so great that the experiment had to be discontinued. The adrenalin seemed to bring on the pain attacks, and then the resistance on each hand dropped to a very low level. The experiments were further complicated by the fact that the body temperature rose very high during the attack. From other work in this connection we have learned that the skin resistance is invariably decreased both by pain and by an elevation of body temperature much above the normal level.

Discussion.

The discrepancy between the results of the hot-air bath and the pilocarpine injection requires special discussion. How can one explain the fact that in the hot-air bath the injured side remained perfectly dry and the normal side sweat profusely, whereas after pilocarpine injection the injured side showed a quicker and greater drop in resistance and sweat sooner and more profusely than the normal side? Two explanations suggest themselves.

As a basis for the first explanation one must recall the general belief that pilocarpine acts peripherally rather than centrally. Luchsinger [2] showed that after the sciatic is cut in the limb of an animal it is still possible to produce sweat by injection of pilocarpine, because the pilocarpine acts in some way on the junction between the nerves and the sweat-glands. Sweating produced by a hot-air bath, on the other hand, is a central phenomenon. The heated blood passing through the heat-centres in the brain causes these centres to send out impulses to the sweat-glands.

With this knowledge, then, the paradoxical results of the present experiments may be simply explained. The hot-air bath did not produce sweating on the injured side because the pathway from the heat-centres was interrupted. Pilocarpine did produce sweating on the injured side because it acts peripherally and does not depend on nervous connections. But why did it act so much sooner and so much more markedly on the injured side? Here it must be assumed that the nerve-endings are more irritable while the nerves are degenerating, or after they have degenerated.

The results obtained from the psychogalvanic reflex are in agreement with this conclusion. Thus, the spontaneous fluctuations which we believe correspond to the impulses from the heat-centres, while very numerous in the hot-air sweating response, were entirely lacking during the pilocarpine reaction. The fact that the specific reflex response to stimuli was much diminished even at first, and soon disappeared completely, suggests that the pilocarpine stimulated the sweat-glands so that they were quickly saturated, and unable to respond further to the impulses from the central nervous system.

The other explanation is based on the assumption of a parasympathetic as well as a sympathetic innervation of the sweat-glands. The activity of the sweat-glands may be dependent on an equilibrium of impulses from those two components of the autonomic nervous system.

According to this theory, the sweat-glands may be grouped with all the other autonomic organs. In the present case, then, the quicker and more pronounced sweating response on the injured side would be explained by the fact that after the sympathetic impulses were removed the balance was destroyed and the parasympathetic system could respond, entirely unhampered, to the parasympathetic stimulant pilocarpine. This is the explanation of Billigheimer [1], who has made observations similar to our own. With Knauer, he studied one patient who sweat spontaneously on the right side of the body and not at all on the left. After an injection of pilocarpine this patient sweat on the left and not on the right. They conclude that there are two kinds of sweat: pilocarpine or vagus sweat, and spontaneous or sympathetic sweat.

A number of points brought out by the present experiments, however, oppose such an interpretation. If parasympathetic fibres reached the left side in our patient, one would certainly have expected to find a psychogalvanic response, and none was found. Furthermore, atropine, which we know paralyses the parasympathetic endings and should bring about an increase in resistance on the left side, affected the normal side only, without influencing the other side at all. We may add here, also, that in cats and monkeys we have never succeeded in obtaining a psychogalvanic reflex by stimulation of the posterior roots, through which the parasympathetic impulses are believed to pass. Schilf, likewise, could show no response in this way on frogs. In view, moreover, of the failure of anatomists thus far to demonstrate any connection between the parasympathetic nervous system and the sweat-glands, the parasympathetic theory does not seem to warrant much emphasis.

Minor [3] has also described an increased electrical resistance of the skin on the side of a sympathetic lesion, especially after large quantities of aspirin had been given. He worked on eleven patients, nine of whom gave clinical evidence of an unilateral sympathetic paralysis and two of an unilateral sympathetic irritation. In eight of the nine cases with the paralysis there was a higher resistance on the side of the lesion, and in the other it was about the same. In the two patients with the irritation, the resistance was lower on the irritated side. Minor thinks that the difference in resistance as measured on the skin of the face should be grouped with the constricted pupil and the ptosis as a definite sign of a cervical sympathetic lesion.

The results of the present experiments confirm Minor's work. However, because of the large fluctuations which occur from day to day in the resistance of both the injured and intact side, and because of the

close dependence of resistance on emotional stimuli, records taken on a single day would be of doubtful diagnostic value.

Summary.

The psychogalvanic reflex and the electrical skin resistance were examined on the two sides of the body in a patient with a unilateral lesion of the sympathetic chain, showing all of the clinical symptoms which usually accompany such a lesion (contracted pupils, enophthalamus, ptosis, and increased skin temperature).

(1) The psychogalvanic reflex was consistently absent on the affected side. This fact demonstrates definitely the dependence of the psychogalvanic reflex on the sympathetic nervous system.

(2) By placing one electrode in contact with the skin of the affected side and the other on the normal side, it was possible to distinguish that component of the total galvanic response which is produced by the palm and that produced by the back of the hand. It was found that the fast and short deflections occurring one to two seconds after the incidence of the stimulus are set up exclusively by the palm, while the slow prolonged deflections occurring about four seconds after the stimulus are produced both by the palm and back of the hand. Evidence was presented showing that the quick phase is probably dependent on the sweat-glands and the slow phase on capillary and epithelial cell activities. Records from a patient suffering from congenital absence of sweat-glands gave only a slow prolonged deflection.

(3) The resistance of the skin, notwithstanding its high temperature, was in general slightly higher on the affected side. In the hot-air bath, the resistance on this side remained high, while that of the normal side showed the usual sudden drop almost to a zero level. The side of the lesion, although very warm, remained perfectly dry; the other side sweat profusely at the height of the reaction. There were marked spontaneous psychogalvanic fluctuations on the normal side, and none at all on the injured side.

(4) Sweating produced by pilocarpine gave an opposite result. Here the resistance on the affected side dropped to a zero level almost instantaneously after the injection, and the skin broke out in sweat shortly afterwards. The resistance on the normal side did not reach the low level until almost thirteen minutes later, and sweating did not begin until then. The spontaneous psychogalvanic fluctuations were absent. It was pointed out that the difference between the sweat bath

and pilocarpine experiments can be explained in two ways, one on the assumption of a parasympathetic innervation of the sweat-glands, and the other on the basis of a heightened response of degenerating nerves or terminal synapses to the pilocarpine stimulation.

(5) Atropine produced an increase in the resistance of the palm on the normal side, and had no effect at all on the injured side. Adrenalin was injected also, but, due to the increased pain produced by the drug, the records were too complicated to enable us to draw any conclusions.

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A CONTRIBUTION TO OUR KNOWLEDGE OF THE ARTERIAL SUPPLY OF THE CEREBRAL CORTEX IN MAN.

BY JOSEPH L. SHELLSHEAR,

Professor of Anatomy, University of Hong-kong.

Introduction.

This report is part of a general research into the principles underlying the distribution of the arteries of the body. It seems to the writer that the time has come to examine the vascular distribution in a purely morphological way, not primarily to lay emphasis on the clinical aspect of the subject, but to give an account of the vessels in terms of their final areas of supply.

It is felt that researches dealing with the distribution of the sympathetic nervous system will be facilitated by such a purely morphological investigation. Up to the present, with certain exceptions, the examination of the arteries has been almost exclusively confined to the major distributing trunks which lie outside of the actual structures supplied with blood. The arrangement and variations of the circle of Willis, and of the larger arteries related to it, have been critically examined, whilst little has been written on the exact distribution of the terminal branches of these arteries. The exceptions to this are found in the works of Heubner [7], Duret [5], Beevor [1] and Stopford [15].

Their writings would seem to indicate a greater constancy in final supply than the variations of the distributing trunks would appear to suggest. Duret has not given details of the method he employed, but he appears to have combined the method of injection with dissection. He found that the areas of supply of the three cerebral arteries and even of their secondary branches were fairly constant.

> "Nous croyons qu'on peut préciser davantage et énumérer les convolutions qui sont vascularisées par leurs premières branches de division : le territoire de chacun d'elles est assez constant" [5].

He mapped out areas for certain individual branches of these arteries, and his pictures form the basis for illustrations in textbooks

to-day. Beevor used a method of injection in which the pressure at the various points of injection was equalized. In the main his results agree with those of Duret, and where this is not the case there is no evidence to show that the discrepancies were not due to anastomotic overflow. Stopford used the method of injection combined with the dissection of individual branches in the determination of the arterial supply of the pons and medulla. A careful review of the works of these three writers reveals the fact that in a large number of cases there appear to be autonomous vascular areas. These autonomous areas were clearly recognized by Charcot [3], and his writings would seem to indicate that he was seeking a functional explanation for them. Duret refers to the first cortical branch of the middle cerebral artery supplying the inferior frontal convolution; he says:—

> "C'est cette convolution dont on a considéré la lésion comme étant plus particulièrement la cause de l'aphasie."

This raises the important question of localization of function in the cerebral cortex in relation to the problem before us. Henry Head [6] has, by his researches on aphasia, forced us to regard the whole question of cortical function from a different and wider viewpoint.

In the problem before us of the relation of separate arterial fields to cortical areas, what areas of the cerebral cortex are we to regard as functional? Since the time when Duret and Beevor did their work the science of cerebral localization has been advanced by the purely morphological researches of many workers, in the forefront of whom are Elliot Smith and Brodmann. Elliot Smith, by his insistence on the phylogenetic approach in studying the homologies of the cerebral sulci, has laid the foundation for the comparative study of the relationships of vascular autonomous areas to defined and constant sulci [13]. He and Brodmann have also mapped out cortical areas of distinctive structure which we may also compare with vascular areas [2] [14].

In other parts of the body it is fairly easy to define what is meant by the term "functional"; for example, the structures employed in the act of mastication might be regarded as a functional group; and the hypoglossal nucleus might be regarded as a functional unit. In the cerebral cortex the definition is not so easy, for the several parts of the cortex are so interrelated that the independent functioning of any one part is unlikely; nevertheless, having due regard to this, it seems reasonable to look upon such areas as the visual or striate cortex concerned with the reception of sensory impulses as having a definite functional value. Between these sensory receptive areas and the higher

motor centres lie areas of greater complexity. Are these to be regarded as functional units? In the present state of our knowledge the question is better left unanswered; but there can be no doubt that if the arterial distribution is precise, then the determination of the relationship of vascular areas to the sulci and to those areas which have been mapped out by Elliot Smith and Brodmann should further the study of cerebral localization.

Morphological problems present themselves, in the solving of which the writer of to-day has all the advantage of the newer methods and fuller knowledge to help him. These problems comprise:—

(1) The determination of the relationship of the arteries to the distinctive areas of the cerebral cortex.

(2) The constancy, or otherwise, of the final areas of supply.

(3) The evolution of the cerebral arteries; and, thereby, the determination of the means by which the primitive arterial supply adjusted itself to the demands of the ever-increasing neopallium.

The lines along which these problems are being attacked are set forth above. It will be seen that the foundations are laid on morphological findings which cannot be disputed. Furthermore, before setting forth the vascular relationships of the cerebral cortex, the writer has confirmed, in the Chinese and in a large series of orang, gibbon, and other brains, Elliot Smith's morphological interpretation of the homologies of the sulci with which this paper is concerned, as well as the relations of the visual cortex to the sulci in the region of the occipital pole [13] [9]. The work of Duret, Beevor, and Stopford has been verified in almost every particular. Any discrepancies between their results and mine have been slight, and then only in the direction of minuter analysis; for example, the claustrum was found to be supplied by a separate artery and not from the cortical arteries [10]. This is not so much an error in the results of Duret and Beevor as an analysis of the middle cerebral artery.

Yet another group of observations has a bearing on the problem. The work of Elliot Smith on the origin of the neopallium proves that the relationships and identity of the primitive fore-brain structures remain fixed throughout the vertebrate series. The neopallium is interpolated between the pyriform cortex and the hippocampal formation [15]. The growth and differentiation of the neopallium seem to be a continuation of this process of interpolation. In a series of observations, which I am now making, on the arterial supply of the brains of lowlier forms, I find in the crocodile, in echidna and in

macropus, that the arterial supply of the primitive fore-brain structures is constant. The pyriform cortex is supplied in a very definite way by three branches of the middle cerebral artery, and the hippocampal area in the crocodile is supplied by a large artery (probably the anterior choroidal). Without entering into a discussion of the homologies of the posterior cerebral group of arteries, it is established that the region of cortex lying between the pyriform and hippocampal areas is supplied by the anastomotic field between the arteries of supply to these two primary areas. This would seem to indicate that the interpolated areas are developed at the periphery of the blood-stream; and, therefore, some of the most important areas of the brain may not be autonomous areas but may lie at points of vascular junction. Whilst my observations do not yet justify a dogmatic assertion on this matter, it has been raised lest the reader might infer from the observations to be recorded that a definite artery might be expected for each of the distinctive cortical areas of the cerebrum.

Material and Method.

The brain described in this communication is that of a Chinese male. The vessels were injected by the method of Beevor; but, besides using the colour as a guide, the vessels have been individually followed to their termination. It is obvious that the determination of the line of demarcation between vessels injected by the same colour is somewhat arbitrary; and since it is impossible to determine the histological boundaries in the same specimen, the observations are put forward with some degree of reserve. The gross distribution of the vessels has been confirmed in other Chinese brains, and, furthermore, the distribution is in keeping with the observations of Duret. The arterial supply of the occipital region in specimens of orang, gibbon, chimpanzee, and gorilla, has also been examined and the results incorporated.

Acknowledgments.

I have to acknowledge my deep sense of gratitude to Professor Elliot Smith for his help and advice in this work, and for the privilege of working in his department at University College, London, whilst on furlough from Hong-kong.

For the supply of orang and gibbon brains I have to express my indebtedness to Messrs. Boden Kloss, Chasen and Smedley, of the Raffles Museum, in Singapore.

Finally, I gratefully acknowledge that the publication of this and

other papers has been made possible by the Chancellor, Sir Cecil Clementi, and Council of the University of Hong-kong.

For figs. 1, 2, 3 and 4, I am indebted to Mr. T. L. Poulton.

General Description.

The Posterior Cerebral Artery.

The area of distribution of the posterior cerebral artery is shown in figs. 1, 2, 3 and 4. If these figures are compared with those of

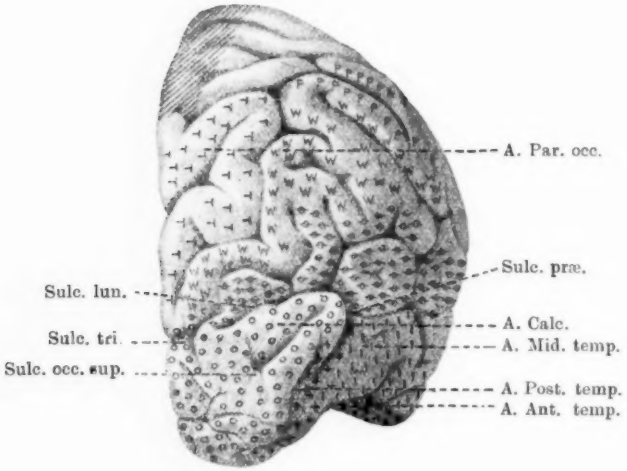


Fig. 1.—The arterial distribution of the occipital region in a Chinese male. The sulcus lunatus is broken medially into a sulcus lunatus proper, and a pars mesialis sulcus lunatus (see figs. 5 and 6).

Duret and Beevor, substantial agreement will be found in the distribution. Before entering into a detailed description of the specimen, it is convenient to digress for a moment in order to discuss the morphological significance of the sulci in the occipital region. In the brain of the Chinese one finds a very large percentage of cases in which the sulcus lunatus is clearly recognized as a fully curved operculated sulcus extending well on to the lateral surface of the hemisphere; and its attendant sulci paramesialis and prælunatus bear a constant relationship with it (fig. 5) [11]. Furthermore, in the majority of cases the line of Gennari is coincident with the posterior lip of the sulcus

lunatus. The sulcus lunatus, when present, is found in one of two conditions; either it exists as a fully curved sulcus, extending from the infero-lateral border of the hemisphere to a point close to the medial border immediately anterior to the inner end of the sulcus occipitalis superior, two constant sulci being found connected with it —the sulcus

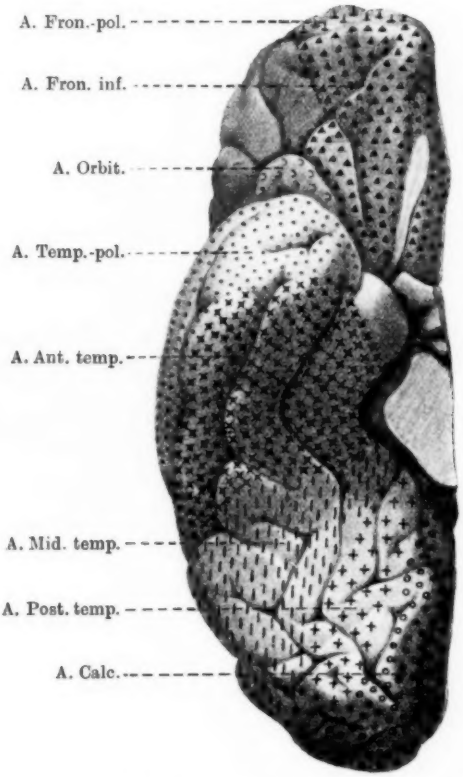


FIG. 2.—The arterial distribution to the inferior surface of the brain. The lines of demarcation between the anterior, middle and posterior temporal areas is somewhat arbitrary.

paramesialis medially and the sulcus prælunatus laterally. In the second condition the sulcus lunatus is broken on the medial side; this break is due to the insinuation of the "pli de passage supérieur" of Gratiolet (fig. 6). When this condition is present the sulcus paramesialis is invariably connected with the medial segment, and the

sulcus prælunatus with the lateral segment. The inner segment of the sulcus lunatus—the pars mesialis sulci lunati—thus forms a triradiate sulcus on the medial border of the hemisphere. The line of Gennari bears a different relation to the two elements of the sulcus lunatus; it is limited by the lateral segment, whereas the area striata only involves the lower half of the pars mesialis sulci lunati, the upper half of this sulcus being outside of the striate area. These findings were published before the brain under consideration was injected [11].

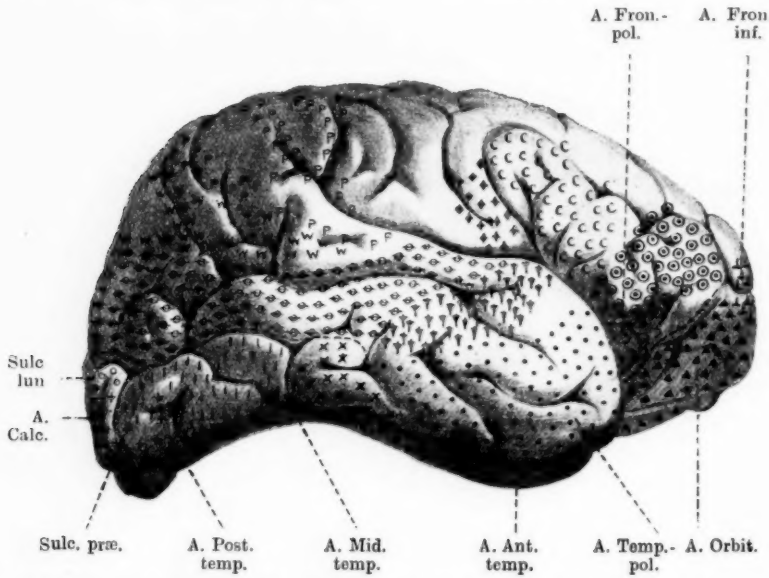


FIG. 3.—The arterial distribution to the lateral aspect of the brain. The line of demarcation between the three major arteries is shown. The distribution of the middle cerebral artery is tentative.

We are now in a position to examine the occipital region in the injected specimen. In fig. 1 the line of separation of the vascular area of the posterior cerebral artery from that of the middle cerebral artery is shown. The blue colouring mass, with which the posterior cerebral artery was injected, is limited by the boundary of the arcus parieto-occipitalis above; then, meeting with the sulcus paramesialis, the boundary follows this sulcus for a short distance and then crosses the middle point of the pars mesialis sulci lunati. We have here the type of lunate sulcus which is broken, and a triradiate sulcus is present on

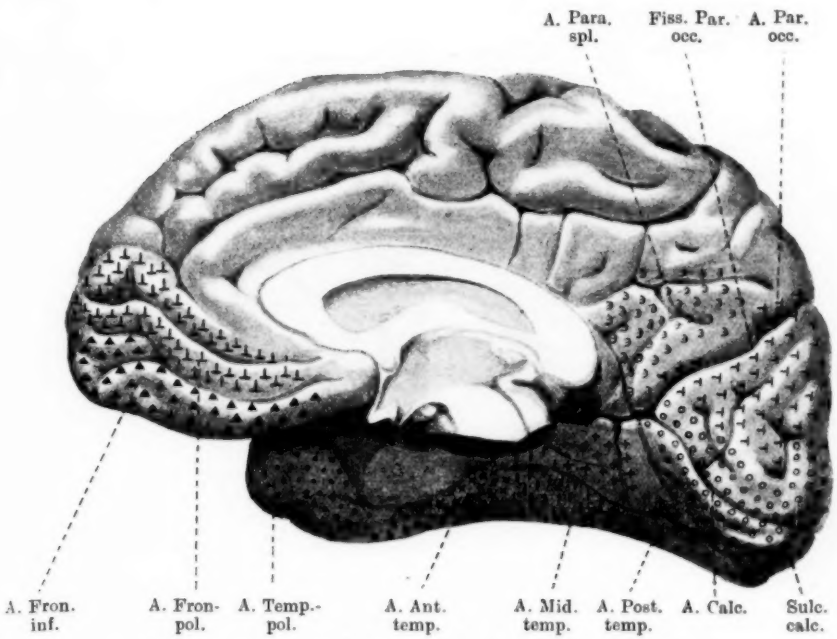
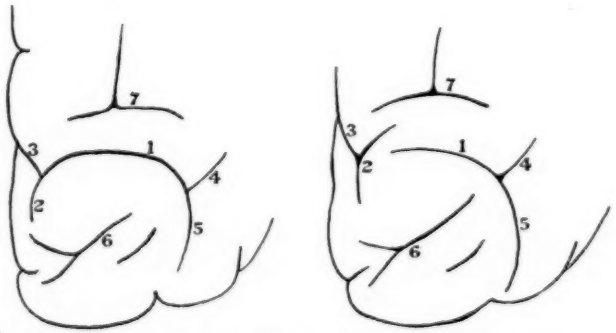


FIG. 4.—The arterial distribution to the mesial aspect of the brain.



FIGS. 5 and 6.—Diagrams of the occipital region of the brain, to illustrate the method of formation of the triradiate sulcus on the mesial side. This sulcus is composed of the sulcus paramesialis and the pars mesialis sulci lunati, *cf.* fig. 1. 1, Sulcus lunatus proper; 2, pars mesialis sulci lunati; 3, sulcus paramesialis; 4, sulcus prælunatus; 5, lateral extremity of the sulcus lunatus; 6, sulcus occipitalis superior; 7, sulcus occipitalis transversus.

the medial border of the hemisphere. The upper half of the pars mesialis sulci lunati belongs to the middle cerebral area, and the lower half to the posterior cerebral area. The boundary now follows the

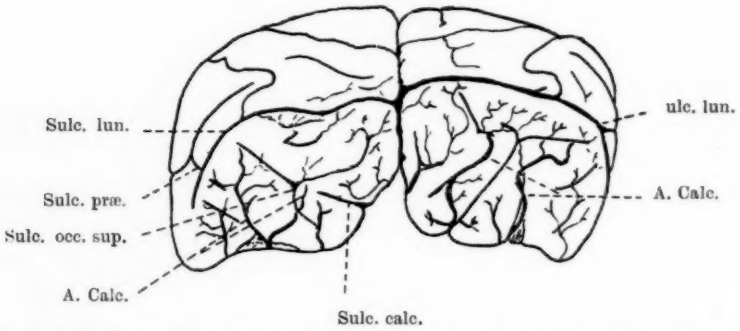


FIG. 7.—The occipital region in the orang-utan. In this specimen the injection was confined to the posterior cerebral area. The striate cortex is defined by the arterial supply.

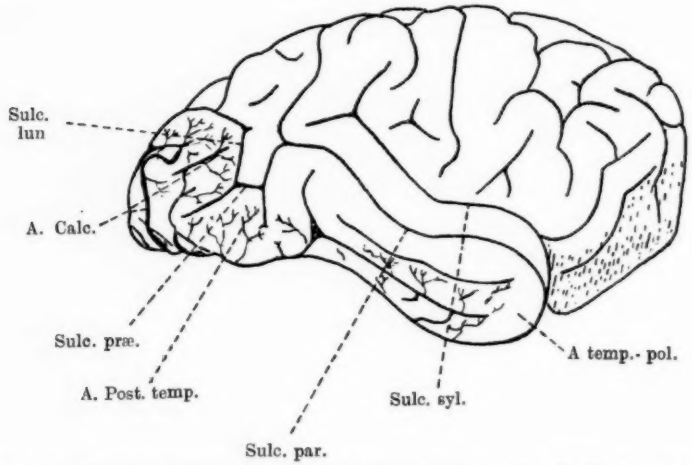


FIG. 8.—The lateral aspect of the brain of the orang-utan. The distribution of the posterior cerebral artery in this specimen is very similar to that shown in fig. 3.

sulcus lunatus to the point at which the sulcus prælunatus arises, beyond which the sulcus prælunatus separates the two major vascular areas. A section through the sulcus lunatus demonstrates the coincidence of the line of Gennari with the blue colouring of the injection

of the posterior cerebral artery. This coincidence would be sufficiently striking if we were merely considering the gross distribution of the posterior cerebral artery ; but it becomes more so when we consider the distribution of the calcarine branch of the main artery. The limits of the distribution of this branch coincide almost exactly with the visual or striate cortex, both on the mesial and lateral surfaces of the hemisphere in this brain. In the brain of the orang-utan, described by

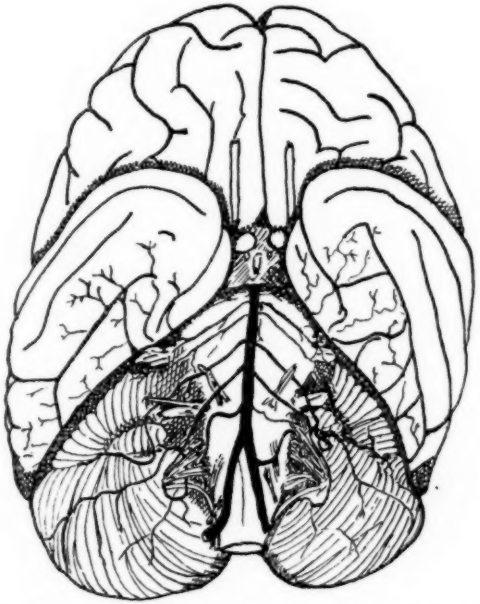


FIG. 9.—The ventral aspect of the brain of the orang-utan in which the area of the posterior cerebral artery was injected.

me [12], the distribution of the calcarine artery likewise almost exactly delimited the striate cortex.

When passing through Singapore in December, 1926, after the above observations were made, Mr. Smedley presented me with the brain of the orang-utan depicted in figs. 7, 8 and 9. He apologized for the incomplete nature of the injection. I would rather tender my thanks for the incomplete injection, because it was limited to the posterior cerebral area on both sides. It does not require separate description; but one feature of the distribution deserves special

mention as having a bearing on the problem before us. In other brains which I have examined, the calcarine artery is generally a large artery lying in the depths of the calcarine fissure. In this specimen the artery within the fissure is small and extends very slightly beyond the limits of the fissure in its distribution. The arteries to the striate cortex on the lateral surface arise from the posterior temporal branch distal to its origin from the posterior cerebral artery. Does the fact that the calcarine artery arises as a group of vessels, in place of a single branch, detract from regarding the striate cortex as an autonomous vascular area?

The association of the calcarine artery with the striate cortex has been previously noted [4], but its significance as a morphological problem of more universal application has not been appreciated heretofore. The reason for this, no doubt, lies in the fact that the lateral extension of the striate cortex is limited in the European, and at the same time variable in extent. The variability of the extent of the posterior cerebral artery is not therefore of necessity evidence of inconstancy of arterial supply. The variability which Beevor found is now readily explained on morphological grounds; and at the same time it reveals the faithfulness and accuracy of his observations. He found that:—

> "The posterior cerebral area did not extend on to the outer surface at all at the horizontal level of the posterior pole in nineteen cases out of seventy-seven, and did not even reach the occipital pole on the median surface in one case, while in twelve it extended for $\frac{1}{4}$ to $\frac{1}{2}$ in. from the occipital pole to the outer surface along a line drawn from the upper end of the fissura extrema of the calcarine fissure to the angle of the parallel sulcus" [1, p. 35].

In nineteen cases its extent was greater than this, but there is no evidence to show that the extension was due to this particular branch of the posterior cerebral artery, or that overflow from other arteries had been ruled out.

The calcarine artery has been dealt with first because it is the one cortical artery whose distribution can be compared by naked-eye examination with a known cortical territory. The determination of the relationship of the arterial supply to other cortical areas is a more difficult matter. Ariens Kappers fully discusses the question as to whether the sulci are reliable guides to the intrinsic pattern [9]. The answer may best be given in his quotation from Elliot Smith:—

> "A sulcus which lies at the margin of a definite histological formation in one brain may be *strictly homologous* to a furrow in another brain, which is far removed from the edge of this cortical area, because the intervening area has transformed in structure; and he emphasizes how misleading the inferences as to homologies may be when based solely upon the evidence of the structure of the cortex."

For this reason it is difficult to say whether the other arteries to be described correspond as accurately with cortical areas as does the calcarine. The similarity of the charts showing the vascular distribution to the charts showing cortical areas are so striking, however, as to suggest a definite relationship to one another.

Duret classified the branches of the posterior cerebral artery into anterior and posterior temporal, and occipital. His occipital branch has since been subdivided into calcarine and parieto-occipital branches. In the orang and in man I find that there are three temporal branches more commonly than two, in keeping with fig. 762 in Cunningham's "Textbook of Anatomy" [4]. A comparison of this figure with fig. 585 in the same work provides a striking introduction to the description of the arteries in the specimen under consideration, for there is a close correspondence between the areas supplied by these individual branches of the posterior cerebral artery and the areas mapped out within its total area of supply. It is proposed, therefore, to name these branches anterior, middle, and posterior temporal.

The trunk of the anterior temporal artery is sometimes replaced by two or three subsidiary branches from the main artery, but the origin from a single trunk is the commonest condition. The area of distribution of this vessel is found by me to be somewhat greater than that described by Duret. The area is wedge-shaped with the base of the wedge situated laterally and formed by the inferior temporal sulcus. The anterior boundary is sharply defined by the line of demarcation between the middle and posterior cerebral injections. The temporal pole is never supplied by the posterior cerebral artery, which is in entire agreement with the findings of Duret and Beevor; in fact, if there is any anastomotic connection between the arteries at this point it must be very slight. The cortical region of the temporal pole is the area temporo-polaris of Elliot Smith—area 36 of Brodmann. It is invariably supplied by a branch of the middle cerebral artery. The base and anterior boundary of the wedge-shaped anterior temporal vascular area define two of the boundaries of area 20 of Brodmann; for

area 20 lies immediately posterior to area 36, and the lateral boundary is shown by Brodmann to lie a very short distance above the inferior border of the hemisphere—in fact, on the level of the straight sulcus seen in fig. 2, which is the inferior temporal sulcus. The lateral limit of the posterior cerebral invasion at this point is confirmed in the figures of Duret and Beevor. The line of demarcation between the anterior and middle temporal arteries is shown in fig. 3; it provides the posterior boundary of the wedge-shaped area.

The middle and posterior temporal arteries together supply an area which closely corresponds to the area supplied by the posterior temporal branch of Duret. The distribution of the middle temporal artery is confined to an area which closely corresponds with area 37 of Brodmann. I have confirmed this in other brains in the Chinese and have also noted its presence in the orang-utan. As far as I am aware, no area 37 has been found in the orang, but the presence of the vessel may indicate the beginning of the evolution of this area.

In the injected specimen the line of demarcation between the middle and posterior temporal arteries is well defined on the tentorial surface (fig. 2), where the distribution of the posterior temporal artery corresponds closely with the areas peristriata and parastriata of Elliot Smith—areas 18 and 19 of Brodmann. The line of demarcation between these two vessels could not be determined with certainty on the lateral surface of the hemisphere. Here, however, the line of separation between the middle and posterior cerebral arteries is clearly defined by the sulcus prælunatus, and the same condition is seen in the orang. In this way the arterial supply gives additional evidence of the morphological importance of this constant sulcus in the anthropoids.

The line of demarcation between the posterior temporal and calcarine areas is clearly defined. The area of the calcarine branch, below the level of the sulcus prælunatus, passes just inside the lateral extremity of the sulcus lunatus (fig. 1). Thus the area of the posterior temporal artery insinuates itself between the calcarine area and the sulcus lunatus in this region. The distribution of the vessels at this point is very suggestive in the light of the morphological description of the sulcus lunatus in the brain of the Egyptian by Elliot Smith and in the brain of the Chinese by myself [13] [11]. On the medial side the expansion of the cerebral cortex, belonging to the middle cerebral area, has insinuated itself between the pars mesialis sulci lunati and the sulcus lunatus proper. The upper limit of the striate cortex passes across the middle of the pars mesialis, so also does the vascular line of

demarcation. The "pli de passage supérieur" of Gratiolet is supplied by the middle cerebral artery. On the lateral aspect I have frequently noted that the dependent lateral extremity of the sulcus lunatus did not limit the line of Gennari; it fell short of it. There is sometimes even a separation of this lateral extremity as a distinct sulcus, predicting the condition seen in the European brain. (The reader is here referred to figs. 6, 10, 26, 28 and 30, in my paper on the occipital lobe of the Chinese.) When this fact was noted the work of Elliot Smith on the morphology of the human brain [13] was not available. He says (p. 152) :—

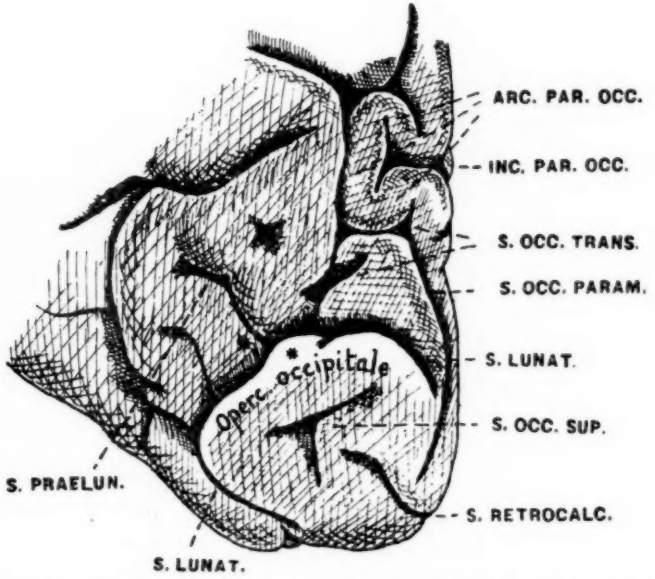


FIG. 10.—The occipital region in the Egyptian brain, showing the morphology of the sulcus lunatus in the region of the sulcus lunatus. (Elliot Smith, fig. 28 (13).)

"Fig. 27 represents the lateral aspect of a large Egyptian brain presenting a characteristic occipital operculum. In this case a sulcus passed forward from the midpoint of the convexity of the lunate sulcus. On pulling the small operculum backwards this furrow, which I shall call 'prælunatus,' was found to be continuous with the upper half of the lunate sulcus and a submerged gyrus crossed the latter (see the arrow in fig. 27), separating it into two distinct parts. It often happens that this gyrus comes to the surface and divides the lunate sulcus into a

pars dorsalis and a pars ventralis. Fig. 28, which represents a very oblique (dorso-caudo-lateral) view of the occipital region, gives a better idea of the lunate, prælunate and paramesial sulci. The two astericks (* *) represent the situations of the extremities of the gyrus translunatus.

With his permission, his fig. 28 is here reproduced as fig. 10.

The retreat of the striate cortex to entrench itself on the mesial aspect of the brain of the European follows upon the pressure exerted on the flanks of the exposed area. It gets pinched, as it were, between the pars mesialis and the pars ventralis, whilst the lateral occipital sulcus remains and represents the pars dorsalis still connected with the sulcus prælunatus. The direction in which the cortex is expanding is revealed, therefore, not only by the examination of the sulci in relation to the striate cortex, but also by the arterial distribution in this specimen.

The parieto-occipital branch of the posterior cerebral artery enters the parieto-occipital fissure and is distributed mainly to the cuneus, on the medial surface, and to the arcus parieto-occipitalis on the lateral surface. The extent of the buried cortex within the fissure suggests a further subdivision of its branches. This, however, has not been attempted here (fig. 4).

The line of separation between the anterior and posterior cerebral arteries, and the distribution to the precuneate area, could not be determined on account of failure of the injection in this region and some damage to the vessels. There is no doubt, however, that the descriptions of Duret and Beevor are correct and that the line of demarcation is somewhat variable. In this specimen a branch of the posterior cerebral artery passes to the area parasplenialis of Elliot Smith. In the brain of the orang, described by me [12], this area was supplied by a branch of the anterior cerebral artery. The variability of the line of demarcation in this region would seem to indicate that the anastomotic connection between the anterior and posterior is free, in contradistinction to the apparent absence of free communication at the temporal pole.

The Anterior Cerebral Artery.

The cortical area supplied by this artery was not completely injected, and the specimen was somewhat damaged in the region of supply of the posterior medial frontal branches. The regions, however, where the distribution can be determined are so exact, and so similar to those in the orang-utan, that their description is here warranted, although the main object of the record is to describe the posterior cerebral area.

The first cortical branch is a small artery given to the gyrus subcallosus. It frequently arises from the recurrent branch of the anterior cerebral artery. The second branch is the *inferior frontal artery*. Its area of distribution is the same in man as in the orang. It arises close to the anterior communicating artery, passes forwards for a short distance on the mesial side of the gyrus rectus, and, after giving a branch to the mesial aspect of the hemisphere, turns outwards to pass between the olfactory tract and the orbital surface of the hemisphere. Its supply is purely cortical to that area which lies between the sulcus subrostralis on the mesial surface of the hemisphere and the sulcus orbitalis on the orbital surface. Anteriorly the area of supply falls just short of the frontal pole, where it is limited by a transverse sulcus. The line of demarcation between the anterior and middle cerebral arteries forms the lateral border of this vascular area. The line agrees with the findings of Duret. It is to be noted that in this specimen the area orbitalis of Elliot Smith (see Cunningham's "Textbook of Anatomy," figs. 585 and 589) is bounded by a circular sulcus which indents the line of vascular demarcation. In this way the fact that this area is supplied by a distinct branch of the middle cerebral artery is accentuated, although in point of fact the vascular area extends for a quarter of an inch anterior to the curved sulcus (fig. 2). The area of supply of the inferior frontal artery is thus roughly triangular and exactly delimits the area præfrontalis of Elliot Smith. Duret's description requires some modification in this region, for he has confused this purely cortical artery with the recurrent branch of the anterior cerebral artery. The recurrent branch supplies the tuberculum olfactorium in part, the head of the caudate nucleus, the olfactory tract and the olfactory bulb [10]. It occasionally inosculates with the branch of the middle cerebral artery which supplies the basal nuclei; in fact, the recurrent branch is intimately associated with the middle cerebral artery in supplying these primitive fore-brain structures. It never supplies the cerebral cortex. The inferior frontal artery alone supplies the gyrus rectus and the medial orbital gyrus. I have found the supply of this artery to be constant in man and the orang. The third cortical branch of the anterior cerebral artery is likewise constant in its distribution. It supplies the area fronto-polaris of Elliot Smith. The area of its distribution lies between the sulci subrostralis and rostralis on the mesial surface; on the lateral surface it supplies the anterior region of the superior frontal convolution (fig. 4). The remaining distribution of the anterior cerebral artery could not be determined.

The Middle Cerebral Artery.

No attempt is made in this communication to describe the individual branches of the middle cerebral artery. Mention has been made of two of the branches related to cortical areas—the branches to the areas orbitalis and temporo-polaris. The figures show the various lines of demarcation between the major arterial supplies, and in fig. 3 a tentative subdivision of the branches of the middle cerebral artery is shown.

SUMMARY.

(1) The distribution of the posterior cerebral artery, and of those branches of the anterior and middle cerebral arteries which have been described, bears a close correspondence with the areas of the cerebral cortex which have been mapped out by macroscopic and microscopic methods.

(2) The arterial supply of the cerebral cortex is precise in its distribution, and might be used as an auxiliary to other methods of determining cerebral localization.

(3) The precision of the arterial supply of the cerebral cortex adds confirmation to the law of arterial distribution in relation to function, first enunciated by John Hilton [8].

Note.—The major part of the above observations were made in Hong-kong, where the available literature is scanty. The writer has since had access to a series of papers by Foix, Masson and Schiff-Wertheimer. These papers deal with the clinical aspect of the subject, and, since this communication is solely concerned with the morphological aspect of the distribution, it is deemed inadvisable to discuss the findings of these authors therein. Their papers, however, are so important that they should be read in conjunction with the above observations, for the clinical findings confirm in great measure the morphological ones.

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DESCRIPTION OF FIGURES.

Abbreviations.

The letter A indicates the area of supply of a particular artery.

Branches of the anterior cerebral artery.

A. Fron-pol. The artery of the area fronto-polaris.
A. Fron. inf. The inferior frontal branch.

Branches of the middle cerebral artery.

A. Orbit. The artery of the area orbitalis.
A. Temp-pol. The artery of the area temporo-polaris.

Branches of the posterior cerebral artery.

A. Calc. The area of the calcarine branch.
A. Par. occ. The area of the parieto-occipital branch.
A. Para. spl. The area of the artery to the area parasplenialis.
A. Ant. temp.
A. Mid. temp.
A. Post. temp. The anterior, middle and posterior temporal branches.

Fiss. Par. occ. Fissura parieto-occipitalis.
Sulc. calc. Sulcus calcarinus.
Sulc. lun. Sulcus lunatus.
Sulc. occ. sup. Sulcus occipitalis superior.
Sulc. par. Parallel sulcus.
Sulc. præ. Sulcus prælunatus.
Sulc. syl. Sylvian sulcus.
Sulc. tri. The triradiate sulcus composed of the sulcus paramesialis and the pars mesialis sulci lunati.

Proceedings of the Section of Neurology of the Royal Society of Medicine.

President—Sir JAMES PURVES-STEWART, K.C.M.G., C.B., M.D.

Cases shown at the Clinical Meeting held at the National Hospital, Queen Square, W.C.1, on Thursday, March 10.

Bilateral Ulnar Neuritis in Association with Skeletal Deformities. ? Hypertelorism.

By Dr. C. P. SYMONDS.

T. D., aged 58, attended Neurological Out-Patients at Guy's Hospital on February 26, 1927. Family history unknown. Previous health good. For many years sensibility over the skin of the right little finger has been impaired.

Four years ago he fell 6 ft. on to the right elbow. Since then his grip has been impaired so that he cannot continue his work.

Signs of bilateral ulnar nerve palsy with clawing of the two ulnar fingers and wasting of the small muscles of the hands, hollowing of the palms and flattening of the hypothenar eminences. Sensory loss to all forms of stimulation over the ulnar border of the right hand. Both ulnar nerves lie exposed over deformed external condyles, and are thickened and hard to the touch.

Brachycephalic. Eyes set so wide apart that binocular vision is not possible. Prominent frontal eminences, bridge of the nose flattened. Congenital divergent squint. Terminal phalanx of right little finger deficient. Fundi both show marked appearance of medullated nerve-fibres. Intelligence normal.

The neuritis was regarded as traumatic in origin, for the patient gave a history of repeated injuries to the elbows. Skiagrams of the elbow-joints revealed marked traumatic osteoarthritis, which is probably the immediate cause of injury to the ulnar nerves.

Sir J. PURVES-STEWART agreed as to the diagnosis of delayed traumatic neuritis.

Case of Syringomyelia with Hydrocephalus and Coarse Tremor (Fibrillation) of the Right Hand.

By Dr. C. P. SYMONDS.

A. T., aged 43, attended Neurological Out-Patients at Guy's Hospital on February 9, 1927. For the past three years patient has had attacks of throbbing in the left temple associated with vomiting and double vision. These attacks came every fortnight, but he has not had one now for twelve months.

Four months ago he began to notice coldness and stiffness of both lower limbs. Both legs drag, especially the right.

About the same time the right hand began to shake and he noticed a weakness of the fourth and fifth fingers of that hand. Occasionally there has been numbness of the same fingers of the left hand. He has had difficulty in holding his water.

Patient states that his head has always been large and he has difficulty in getting suitable headgear.

On examination the head is large, especially transtemporally. Slight swelling of the left optic disc. Slight double ptosis. Fibrillation of the tongue.

There is wasting of the intrinsic muscles of both hands, and clawing of the third and fourth fingers of the right hand. Wasting of the right forearm ulnar muscles. There is an extremely coarse tremor of the fingers of the right hand, and fibrillation of the hand muscles and of the ulnar muscles of the forearm. Legs spastic.

Impairment to pressure pain and hot and cold over the right C.8 and Th.1 segments. More extensive impairment to cold over C.6 to L.3 on the left side of the body. Loss of sense of position in toes of the right foot. Vibration sense absent on vertex and tibial malleoli, impaired over radial styloids.

Tendon reflexes all very brisk. Bilateral ankle clonus. Bilateral extensor plantar responses.

Dr. IRONSIDE referred to two other cases in which a very rapid tremor of the fingers was due to fibrillation.

Dr. COLLIER emphasized the briskness of the arm-jerks in this case, and suggested that the fibrillation gave rise to a finger clonus.

Sir J. PURVES-STEWART regarded the hydrocephalus as an expression of upward extension of the cavitation, and suggested pneumoradiograms as a means of determining the diagnosis.

Two Cases of Familial Pes Cavus, with Absent Knee and Ankle Jerks.

By Dr. A. FEILING.

Case A.—T. K., aged 6. Mother complains that patient said his legs ached.

Has a sister, aged 8, who has deformity of feet (Case B); one uncle and one aunt have had many operations for deformity of feet; one great-uncle and one great-aunt also had similar trouble.

Examination.—Healthy boy. Cranial nerves normal. Arms normal. Legs are thin, right more so than the left. No localized wasting. Pes cavus with equino-varus, right much more marked than left; flaccid type. Knee-jerks and ankle-jerks absent. Plantars doubtful. No loss of sensation found.

Electrical reactions: Normal response to faradism.

X-ray of lumbo-sacral region showed no abnormality.

Case B.—O. K., aged 8. Sister of above. Condition similar, but the right foot chiefly affected and condition not quite as marked as in her brother.

No other symptoms. No history of acute illness in either.

The disease was apparently transmitted by the mother, who, though healthy, had a brother, a sister, an uncle and an aunt similarly afflicted. Dr. Feiling regarded the condition as a "forme fruste" of peroneal atrophy.

Dr. SYMONDS referred to the family recorded by Shaw and himself, and also to the cases reported by Roussy and L'hermitte. There was no instance in the literature of the disease being transmitted by a healthy parent, though in one case the father did not show signs of the disease until ten years after symptoms had appeared in his child.

Dr. COLLIER remarked that the majority of cases of peroneal atrophy did not have wasting of the hand muscles.

Dr. TAYLOR disagreed, and thought that at some stage in the disease wasting of the hands was almost always present.

A Case of Schilder's Encephalitis with a Family History of the Disease.

By C. P. SYMONDS, M.D.

W. P., aged 11. *Family history.*—Father is aged 48, and has enjoyed good health, except for an attack of anthrax. He has had defective vision since the age of 12. Mother died of phthisis one year ago.

The history of the children is as follows:—

(1) Male.—Died at two weeks. Cause unknown.

(2) Nellie P., aged 20. Now in Leavesden Mental Hospital; said to have been backward and invalid since birth. Never walked. Has never had any fits. Limbs seemed to become progressively weaker and stiffer as she grew older. Vision thought to be normal by the relatives when she left home for Leavesden Hospital in 1918.

Seen at Leavesden in December, 1926, by the kindness of Dr. R. M. Stewart, who had already made the suggestion that the case might be one of Schilder's encephalitis.

Mentally, she is an imbecile. Vision is very imperfect, but she can apparently distinguish light and darkness. The optic discs are pale and clear cut, the appearance being that of primary optic atrophy; the pupils are dilated and do not react to light; there is divergent strabismus, but no definite ocular paresis and no nystagmus. The right face is weaker than the left when she cries. As she lies in bed the head is somewhat retracted. Both the upper and lower limbs are paralysed and spastic in flexion.

(3) Frederick P., aged 18.—Now in Rotherhithe infirmary with phthisis.

(4) Female.—Died at home, aged 13 months, of "meningitis."

(5) Female.—Died in the infirmary, aged 13 years, of "meningitis."

(6) Jessie P., aged 15.—Alive and well.

(7) William P., aged 11.—Patient shown.

(8) ? Sex.—Died, aged 7 months, of "meningitis."

(9) ? Sex.—Died, aged 9 months, of "convulsions."

(10) Tommy P.—Said to have been normal up till last year, when, at the

age of 6, he was admitted to Guy's Hospital with progressive bilateral weakness. The diagnosis of Schilder's encephalitis was made during life and confirmed at autopsy. (Brain shown.)

(11) Male.—Died, aged 9 months, of "meningitis."

(12) Alfred P., aged 3.—Alive and said to be in good health.

(13) Rene P., aged 1½.—Alive and said to be in good health.

W. P., aged 11.—Had been under observation for the last five years.

As an infant, he developed normally, but began to have fits at the age of 2; this being attributed at the time to a slight head injury. Subsequently, he continued to have convulsive attacks at irregular intervals. According to the mother these usually began with convulsive twitching of the right face, arm and leg, the convulsions would then become generalized and the patient would lose consciousness.

He was first admitted to Guy's Hospital in April, 1919, in one of his attacks, which had begun as usual with right-sided convulsive movements. On admission he was unconscious, but quickly recovered.

Under observation he was thought to be mentally backward and nervous. No localizing signs were found, and he was discharged with the diagnosis of Jacksonian epilepsy.

He was re-admitted in July, 1919, said on this occasion to have had a left-sided Jacksonian attack. On this occasion he was seen by Mr. H. L. Eason, who noted defective vision, especially in the lower fields, and optic atrophy. The Wassermann was negative in the blood and a diagnosis of cerebral tumour was made; he was discharged.

Following this, he had no more attacks until September 14, 1922. On that day he had a series of convulsions, each beginning with twitching of the right angle of his mouth, spreading over the right side of the face, subsequently affecting the right arm and leg. He was admitted unconscious in one of these attacks.

On the next day (September 15, 1922) the fits had ceased, but he was still unconscious. The deep reflexes on the right side were increased and the right plantar response was extensor.

On the 16th he was conscious, but remembered nothing since going to bed on the 14th. The reflexes were as before.

I saw him for the first time on September 22, 1922, and made the following notes:—

"*Cerebration.*—Odd, overactive. Speech: normal.

"*Special senses.*—Visual acuity very fair to rough tests. Fields: some peripheral constriction, especially on right. Discs white and clear-edged, some pigment disturbance around, vessels a fair size, cups not very distinct. I think a primary atrophy.

"*Cranial nerves.*—Pupils dilated with atropine, neither eye turns in very well on conjugate deviation. Slight weakness of right face on emotional movement, otherwise normal.

"*Sensation.*—No defect of sensation.

"*Motor system.*—Left grip better than right, but says he is left-handed.

"*Reflexes.*—All tendon-jerks present and equal on the two sides. Upper and lower abdominal reflexes present and equal on the two sides. Plantar responses: right doubtful, left flexor.

"*Sphincters.*—No disturbance of sphincter control. Walks on a rather wide base and is unsteady. Occiput, if anything, a little to the right; no constant deviation.

"*Impression.*—Cerebro-cerebellar atrophy."

He was again admitted in February, 1925; he was then reported to have had mild fits once a fortnight, or oftener, since his discharge from hospital in 1922. The account given by his mother was that on these occasions, if playing in the street, he would run inside and lie down; after a minute or two, twitching would begin in the right side of the face and extend to the arm and leg; this would continue for a few minutes, after which he would feel quite well again and ready to go out to play. Consciousness was not always lost in these attacks. On the day of admission an attack of this kind was followed by a series, in which he was admitted. Chloroform was given to control the convulsions, which subsided, leaving him dazed and confused. He was discharged ten days later.

Following this, he continued to have fits at irregular intervals, but these lost their Jacksonian character and became generalized. The story is, now, that he is found unconscious, having fallen down.

He was re-admitted in December, 1926, for a month's observation, during which he had one brief attack; he was heard to grunt but, by the time the nurse got to his bed, there was no convulsive movement and he appeared dazed, but was not unconscious.

On examination the physical signs were as before. Physically and mentally he is under-developed, and the optic discs show primary atrophy with general constriction of the fields. An occasional extensor response can be obtained on both sides; otherwise there are no abnormal physical signs.

The Wassermann is negative in blood and spinal fluid. The spinal fluid contains no excess of protein or cells. X-ray pictures of the skull show no abnormality.

Dr. SYMONDS stated that in the literature there was only one other reference to a familial incidence of this disease. The present case had been stationary for five years.

Dr. COLLIER, referring to the pathological specimen, remarked that such a degree of dissemination of the lesions was unusual. Optic atrophy, too, was rare.

Dr. ADIE referred to the importance of blindness with brisk papillary reactions in the diagnosis of Schilder's disease. He doubted the case of familial Schilder's disease referred to in the literature, as in that instance no competent neurologist had seen the case, and the brain was never examined after death.

Two Cases of Thrombosis of Subclavian Artery, with Contralateral Hemiplegia of Sudden Onset, probably Embolic.

By Dr. C. P. SYMONDS.

Case A.—L. S., aged 29. Was admitted to the National Hospital in 1919, under the care of Dr. James Taylor, for left hemiplegia.

The family history was negative.

She had a nervous breakdown with anxiety and depression at the age of 19, and was away from her work (in a drapery business) for three or four months. She quite recovered from this, but subsequently complained of pain in the right arm, from the elbow downwards, and weakness of her hand, which made it difficult for her to hold a pen.

In October, 1915, without previous warning, as she got out of bed one morning she fell on the floor, feeling helpless on the left side of her body. She did not lose consciousness. She has since improved greatly.

On examination, she appeared physically and mentally somewhat backward for her age.

There was weakness of the left side of her face and tongue and upper and lower limbs, with spasticity, increased tendon-jerks, absent abdominal reflexes, and extensor plantar response on that side.

The only other abnormalities observed in the nervous system were slight wasting of the intrinsic muscles of the right hand, particularly of the thenar eminence, with corresponding weakness, abduction of the thumb being particularly affected.

Above the inner half of the right clavicle there was a visible expansile pulsation; on palpation this appeared to be caused by lifting forward of an artery upon a cervical rib.

No pulse could be felt in the right upper limb below this level.

The X-rays showed a large cervical rib on the right side.

The interpretation suggested is that pressure of the cervical rib upon the right subclavian artery led to thrombosis, that the thrombus extended backwards to the point of junction with the right common carotid, and a portion of it becoming broken off formed an embolus in one of the branches of the right middle cerebral artery.

Case B.—I. F., aged 20. Was admitted to hospital in January this year for gangrene of the terminal phalanx of the right index finger and left hemiplegia. The family history is of no importance.

The patient was healthy until three years ago; she was accidentally hit by an air-gun pellet in the right hand, the missile entered the first interosseous space and became embedded there. The subsequent symptoms have been attributed to this injury by the patient. The foreign body was removed six months ago.

Two and a half years ago she began to have attacks of extreme pallor, coldness and numbness in the fingers of the right hand, the index, middle, and ring fingers were succesively involved. These attacks were excited by raising

the hands above the head, as in combing the hair, or by cold; they could be cut short by hanging the arms down by the side of the body or by placing the hand in warm water.

Apart from this, there were no pains, weakness, or paræsthesiæ.

In January, 1926, the terminal phalanx of the right index finger gradually became gangrenous and was finally removed.

In May, 1926, she was having tea when she suddenly felt giddy and dropped her cup. She did not lose consciousness.

A week later she had another similar attack. The following morning she awoke to find herself completely paralysed on the left side. Together with this she had aphasia. From this she has gradually recovered.

On examination, she is mentally somewhat undeveloped for her age. There is no aphasia. Vision, hearing, smell, and taste are normal. There is slight left-sided weakness of face, arm and leg, with spasticity of the limbs, increased tendon-jerks, absent abdominal reflex and an extensor plantar response. A cervical rib can be felt on the right side of the neck. Its presence is confirmed by X-rays. There is no abnormality on the left side. There is some pulsation in a vessel just above the right clavicle, which appears small for a subclavian artery (? transverse cervical). There is no pulsation in the axillary, brachial, or radial arteries on the right side. There is no wasting or weakness in the right hand, nor any sensory loss apart from the abnormalities already described, and the reflexes are normal. There are no signs of general cardio-vascular disease. The Wassermann reaction is negative.

The interpretation suggested is that pressure of the cervical rib upon the right subclavian artery led to thrombosis, that the thrombus extended backwards to the point of junction with the right common carotid and portions of it becoming broken off formed emboli in the terminal branches of the right middle cerebral, leading first to the attacks of giddiness and finally to the left hemiplegia.

Dr. PARKES WEBER referred to a case of his own in which a patient with heart disease had an embolism of the left subclavian, followed later by a right hemiplegia.

Sir J. PURVES-STEWART agreed with Dr. Symonds' explanation, and referred to the war experiences of Sir G. Makins with reference to wounds of the neck.

Dr. CAWADIAS suggested oscillometry for determining the localization and degree of thrombosis.

Dr. CLOAKE and Dr. FEILING thought that carotid thrombosis from cervical rib pressure must be rare.

Dr. PARKES WEBER doubted the advisability of operation on cases of long cervical rib discovered by accident.

Dr. SYMONDS replied that carotid thrombosis had been recorded a great many times (cf. Keen, *Amer. Journ. Med. Sci.*, 1907). A cervical rib could obliterate the carotid and give rise to no other physical signs; possibly such cases constituted a special type of rib. In his own two cases, the ribs were very long ones, and were attached far forwards to the first rib.

Descending Lipodystrophy.

By Dr. M. A. BLANDY.

L. W., female, aged 38.

History.—Since aged 14 has been "thin," as now.

Family.—Is fifth of six siblings. A younger brother is "thin like me."

Condition.—Absence of subcutaneous fat down to the hips. The thighs and legs are quite shapely, although slender. Face looks like a double hemiatrophy, but eyelashes persist, otherwise glabrous. Scalp hair abundant. Has axillary hair. Absence of normal pigment in facial skin.

Wassermann reaction strongly positive. Has old specific choroiditis. No signs of organic nervous disease. Patient came to hospital for rectal prolapse.

The case had a superficial resemblance to double facial atrophy. A positive Wassermann reaction was present in one of the cases recorded in the literature. From the endocrine aspect, her patient's periods did not commence until the age of 19 and were scanty, and her skin is dry.

Dr. PARKES WEBER agreed that Dr. Blandy's case was a very typical one. Lipodystrophy, not confined to the face, has been recorded in males. Improvement has been claimed after the spontaneous commencement of the menses. An increase in weight is not necessarily a sign of improvement. The majority of the patients enjoy robust health. Lipodystrophy has been considered as "first cousin" to muscular dystrophy.

A Form of Familial Periodic Paralysis.

By Dr. BLAKE-PRITCHARD.

Mr. C. H., aged 23, a butcher, who complains of a series of sudden attacks of muscular weakness of sudden onset, commencing at the age of six, with gradual deterioration of strength. The weakness is maximal at the commencement of each attack, and gradually improves over a space of one or two months. His sister, now aged 31, is a subject of exactly similar attacks.

On examination he shows generalized weakness of all voluntary movements, no structural deformity, no muscular pseudohypertrophy, but marked lordosis in standing and bilateral ptosis. The electrical reactions of his muscles are normal throughout.

The case resembles one of myasthenia in many respects, but the lordotic stance recalls a myopathy.

Dr. TAYLOR thought it was an unusual case of myasthenia gravis.

Dr. YEALLAND queried the familial incidence of myasthenia gravis.

Dr. SYMONDS stated that the sister of the patient had been under the care of Dr. Ormerod; she had a variable degree of weakness of the neck and shoulder muscles, and was regarded as possibly a myopathy. She then developed tuberculous caries, and was treated in plaster for eighteen months, at the end of which time she was cured, and has since remained well.

Dr. IRONSIDE asked whether Dr. Adie had thought of dystrophia myotonica in this connection?

Dr. ADIE replied that he had never seen variable weakness in dystrophia myotonica.

A Case of Juvenile Syringomyelia.

By Dr. F. M. WALSHE.

I. W., aged 9. At 6 years of age this child began to drag her right leg, and it was found on examination that both the right arm and leg were weak. Her condition remained unchanged until February, 1927, when her father noticed that her left arm was "not right," and that her left leg seemed to be dragging a little.

On examination the child now shows a double spastic paresis of the legs, with exaggerated tendon-jerks, double ankle clonus, and double extensor responses.

There is a double main-en-griffe with wasting of the thenar and hypothenar eminences and spasticity of both arms. The right limbs are more wasted than the left. There is also a vasomotor paresis in the left hand, which is redder and colder than its fellow.

There is a complete dissociated anæsthesia from C5 to C8 on the right, and from C3 to C8 on the left. She also makes some mistakes over the trunk and legs. There is astereognosis in the right hand, and pinprick localization is poor all over the right forearm. The child also shows a slight but definite lumbo-thoracic curve to the left. No other developmental abnormalities have been noted.

Dr. TAYLOR agreed as to the diagnosis; the earliest case seen by himself came under observation at the age of two years; the patient was seen twenty years later, and there had been no advance.

A Case of Tower Skull.

By Dr. J. S. COLLIER.

E. M., aged 36.—This woman was born after a normal confinement and delivery with a cranial deformity which has since become progressively more noticeable. Until two years ago (1924) she was in other ways as normal as at birth; she had no useful vision in the right eye and was slightly deaf in both ears, worse with the right. Otherwise she has led an active life and with the aid of glasses (worn since the age of 3) has been able to look after herself and read even the smallest type.

Two years ago her sight and hearing both began to deteriorate and since then have steadily become worse.

She complains of no headaches, and vision and hearing have never been otherwise disturbed.

Family.—One brother died as an infant having an exactly similar skull. One (paternal) cousin is now living and although he has a similarly shaped

head the deformity is only slight and he is not blind or deaf. Her paternal grandmother was delivered of two children who died in infancy, both with "hydrocephalus."

Examination reveals a gross deformity of the skull with dislocation of the orbital content and cranial nerve disturbances. She is now under treatment for a recent attack of acute anterior poliomyelitis.

Dr. COLLIER stated that tower skull may appear late in life, whilst oxycephaly was usually congenital. His present case had optic atrophy from narrowing of the bony foramina.

A Case of Olivo-ponto-cerebellar Atrophy.

By Dr. F. M. R. WALSHE.

E. S., aged 67.—This man gives a history extending over the past five years of difficulty in speaking, occasional causeless vomiting, shakiness of the legs and inability to perform finer hand movements. For the last two and a half years he has also been muddled in his head.

The family history and past history show *nil ad rem.* He denies venereal disease and his Wassermann reaction is negative.

There are constant pseudo-athetoid movements of the fingers when the arms are outstretched, best seen in the left hand. Co-ordination is much impaired. All movements are carried out stiffly, jerkily and irregularly, and there is some loss of power in flexion and extension of both elbow-joints. This is also true of the knee-joints, and there is marked inco-ordination in the heel-knee test. Tonus of the limbs is normal. The sense of passive movement is impaired in the feet and toes of both sides. There is no other definite sensory loss.

His right pupil is slightly larger than the left and they both react poorly to light and convergence. There is no nystagmus and no diplopia. Right vision $\frac{6}{12}$ partly, left $\frac{6}{18}$.

There is marked over-action of all the facial musculature, best seen in raising the eyebrows.

There is some Rombergism, and his gait shows a gross amount of swaying and lurching indifferently to either side.

His cardio-vascular, pulmonary and alimentary systems are normal. His optic discs are normal and his cerebro-spinal fluid normal too.

Notices of Recent Publications.

Epidemic Diseases of the Central Nervous System. By A. Salusbury MacNalty. Pp. 194. London: Faber and Gwyer. 1927. Price 12s. 6d.

That acute infective diseases of the nervous system have become more common during the last few decades is beyond doubt, and their epidemiology and the factors that predispose to them are consequently becoming increasingly important. This book, by a well-known authority on public health, discusses these problems fully and in sufficient detail for the ordinary physician. The three diseases dealt with are cerebro-spinal fever, poliomyelitis and lethargic encephalitis.

The various factors that may play a part in the increasing susceptibility of the nervous system to infection are discussed in one chapter. The more easy spread of infection owing to increasing facility for travel is emphasized, but the theory of epidemic cycles, the possible preparation of a favourable soil by successive epidemics of influenza and by the nervous strain of modern life are taken into consideration too. The occurrence of epidemic nervous disorders in animals may be related to it, but it is more probable that these have been for long with us and only recently recognized.

The chapters on the epidemiology of these diseases, on their mode of spread and contagion, and the suggestion for dealing with outbreaks, constitute the main value of this book, but it contains many important observations on symptomatology too.

Therapie der organischen Nervenkrankheiten. Von Max Schacherl. S. 141. Wien: J. Springer. 1927. Price 6.90 M.

This little book will be a valuable addition to the libraries of all neurologists; in it the author deals with the treatment of organic nervous diseases in a concise but adequate manner. The text is evidently based on his own experiences, but he has not neglected therapeutic measures recommended by reliable authorities. Almost half the book is devoted to the treatment of nervous syphilis; in addition to the ordinary remedies, malarial infection and the various forms of shock and pyrexial therapy are discussed. Here, too, there are chapters on the treatment of ataxia and of the ocular and arthritic lesions of tabes. The chapters on the management of disseminated sclerosis, encephalitis, poliomyelitis and other diseases will be instructive to English readers, who will find certain methods and drugs recommended with which they are not familiar. There are also sections on hormone therapy and on electrical treatment. The distinguishing feature of the book is the rational and common-sense attitude adopted by the author.

Plötzliche und akute Erkrankungen des Nervensystems. Von S. FLEISCHMANN. S. 301. Berlin: S. Karger. 1927. Price 12 M.

This book, the author explains in his preface, consists of a series of lectures on acute diseases and affections of the nervous system which he gave some time ago in Kiew. It contains a large mass of heterogeneous material, which is, however, arranged more or less systematically. The first chapters are devoted to cerebral hæmorrhage, embolism and thrombosis and cranial injuries. A chapter on comatose states, and several on inflammation of the brain and its membranes follow. The spinal lesions included are poliomyelitis, acute transverse myelitis and spinal traumata and hæmatomyelia. In other chapters he deals with polyneuritis, lesions of the separate spinal nerves, the neuralgias, sciatica, headache and even psychogenic disorders. In many respects the information he gives is not up to date, but his sections on treatment are sound. The necessity of such a book is scarcely apparent.

Die peripherischen Lähmungen. Von TOBY COHN. S. 320. Berlin: Urban und Schwarzenberg. 1927.

For the last twenty years or so our knowledge of diseases of the peripheral nervous system has been more or less stationary; it is indeed questionable if we can expect any material advance in either their symptomatology or treatment, yet new textbooks appear yearly in which affections of the individual nerves are described in almost identical words. But Cohn's volume is welcome as there is probably no other in which these subjects are dealt with so fully. The chapters on prognosis and treatment will be particularly useful. Only lesions of the individual cranial and spinal nerves are included in it.

Das autonome Nervensystem. Von E. SCHILF. S. 207. Leipzig: G. Thieme. 1929. Price 16.50 M.

In his preface the author explains that this book is due to the fact that Langley died before his "Autonomic Nervous System" was completed, and admits that it is largely based on Langley's work. It is written from the physiological point of view, an undoubted advantage to the clinician who refers to it to find an explanation of the phenomena which he observes, or who wishes to equip himself with the necessary knowledge for the investigation of medical problems.

The first section describes the anatomy of the sympathetic and parasympathetic systems, and the general physiology and the reactions to drugs of the structures they innervate. In the second part each muscular and glandular organ is dealt with separately, the functions of the afferent autonomic system are discussed and the central autonomic centres of the circulation, thermal regulation and of the sweat glands and the pupils are considered.

This book can be warmly recommended as being up to date, remarkably complete for its size, and systematically and lucidly written.

Das Augenzittern als Gehirnstrahlung. Von J. OHM. S. 326, mit 226 Abbildungen. Berlin: Urban und Schwarzenberg. 1925. Price 21 M.

Ohm is already well known to all ophthalmologists and to many neurologists by his numerous contributions to the study of nystagmus. In this volume most of his earlier work is collected and much new material is added to it. He describes it as an atlas of nystagmus, but this title is scarcely just, for though it contains a large number of illustrations the greater number of its pages is concerned in discussing the nature and significance of the different varieties of nystagmus.

Ohm lays great stress on the importance of obtaining tracings of the movements of the eyes and describes in detail the methods he has employed. Almost all the illustrations are reproductions of his tracings or analyses of his graphs, and it is on these that his explanations and hypotheses are based. These will certainly excite much criticism, but his views are always interesting. A fuller discussion of what he exactly means by "Gehirnstrahlung" would have been welcome; he merely states "da wir nun die periodischen Kräfte, wie Licht, Elektrizität, Wärme, Schall als 'Strahlung' zusammenfassen, so habe ich auch die periodischen Nervenerregungen als Strahlung bezeichnet." On the other hand, miner's nystagmus, to which a large part of the book is devoted, is attributed to a diminution in the frequency and an increase in the amplitude of physiological impulses to the ocular muscles. His experience of the nystagmus that results from disease of the central nervous system is evidently limited, and for this reason at least the book will be of more interest to the ophthalmologist than to the neurologist. An index would have made the volume more useful as a work of reference.

Ataxies aiguës. Par JACQUES DECOURT. Pp. 150. Paris: Gaston Doin et Cie. 1927. Price 18 francs.

This volume deals primarily with a consideration of the ataxia of sudden onset occurring in tabes: the author states at the outset that the occurrence of acute ataxia in this disease is nowhere mentioned in French or foreign textbooks, oblivious of the fact that Gowers described the phenomenon in his "Diseases of the Nervous System," thirty years previously. Seven personal cases are cited, and thirteen others are quoted from the literature. The evidences of tabes prior to the onset of inco-ordination have usually been dormant. The onset may occur over a course of several minutes or hours, or, at the most, several days: the precipitating factors, in the author's cases, are not clear. Ataxias of such sudden appearance respond well to antisyphilitic treatment. Pathologically considered, it is suggested that a sudden meningo-radiculomyelitis more marked over the posterior parts of the cord is responsible, and is characterized by evidences in the cerebro-spinal fluid of an acute inflammatory process.

From the standpoint of differential diagnosis, two disorders are considered

in some detail: firstly, acute polyneuritic ataxia, and secondly, Leyden's acute ataxia. The relation of this latter malady—characterized by transient cerebellar inco-ordination, nystagmus and pyramidal involvement—with disseminated sclerosis, is regarded by the author as unproved.

Les Troubles vasculaires dans le Tabes. Par MAURICE BASCOCONET. Pp. 190. Paris: Jouve et Cie. 1927.

The relative integrity of the cerebral vessels in tabes, and the rarity of hemiplegias despite the syphilitic nature of the disease, have occasioned the author to embark upon a study of the circulatory system in a series of cases. Hypertension is often encountered, but apparently gives rise to no clinical manifestation. Arterio-sclerosis and sudden vascular crises are rare in the course of the disease; and, although cerebral hæmorrhages may be found in the brains at autopsy, foci of softening are uncommon. Using the method of oscillometry, the author concluded that microsphygmia is the rule, macrosphygmia being found only as a transient phenomenon in the presence of developing trophic lesions. The vasodilator reactions are feeble, as determined by immersion in a warm bath. The secretion of sweat and the pilomotor reflex are markedly altered—being exaggerated in the early stages and diminished later. Pallor of the skin and the absence of delayed appearance of the congestive reaction are clinical indications of microsphygmia. The author traces a connection between the presence of bony and articular trophic disturbances and the tendency towards phases of macrosphygmia. The intramedullary vegetative centres, rather than alterations in the blood-vessel wall, are regarded as responsible for the microsphygmia.

Sémiologie des Affections du Système nerveux. Par J. DEJERINE. Pp. 1,220. Paris: Masson et Cie. 1927. Price 190 francs.

The appearance of a reprint of this well-known work is adequate evidence of its recognition as a clinical neurological classic. It differs in no respect from the 1914 edition, except that the index has been somewhat amplified. To those who may be unfamiliar with this volume, it can be unhesitatingly recommended.

Les Syndromes névropathiques. Par A. HESNARD. Pp. 250. Paris: Gaston Doin et Cie. 1927. Price 40 francs.

This volume, which is one of a series—the "Bibliothèque des grandes Syndromes"—deals with the neuroses. The author has approached his subject along purely clinical lines, and deals in turn with the symptomatology of neurasthenia, psychasthenia, the anxiety states, the obsessional syndromes, and hysteria. A chapter on ætiology and psycho-pathology follows, and the author concludes with a short résumé of the various modes of treatment. Despite orthodox hostility, the author believes that psycho-analysis contains the germ of the scientific affective psycho-therapy of the future. The scope of

this work is essentially practical, and is intended for the guidance of general practitioners, rather than the information of the neurologist or alienist.

Les Dystonies d'Attitude. Par ANDRÉ THÉVENARD. Pp. 191. 1927. Price 28 francs.

In a preliminary discussion of the mechanics and physiology of the erect posture, the author emphasizes the importance of the muscular system, and considers the various functional groupings of the muscles concerned in particular attitudes of standing, resting, walking, &c. A clinico-physiological consideration follows of such maladies as torsion spasm, decerebrate rigidity (as encountered in the human subject in tumours of the mesencephalon and vermis and ventricular distensions), athetosis, Wilson's disease and pseudosclerosis. For these various disorders the title of "attitude dystonias" is suggested, and spasmodic torticollis is given as an instance of a localized attitude dystonia. The concluding chapter treats with the neurological aspect of posture, and deals with the result of animal experimentation. The red nucleus is given as the chief regulator of tonus, inhibiting the centres in the pons and medulla; release of this inhibition gives rise to decerebrate rigidity. Besides this fundamental mesencephalic mechanism other subsidiary tone-regulators must be considered, i.e., the cerebellum, the labyrinths, the basal ganglia and the pyramidal tract. There is a good bibliography and several interesting photographs, badly reproduced.

Compendium of Regional Diagnosis in Affections of the Brain and Spinal Cord. By ROBERT BING. (Translated from Sixth German Edition by F. S. Arnold.) Pp. 204. Third Edition. London: W. Heinemann.

This useful little work is too well known to require comment; the present edition bears no essential additions to the text, but many of the illustrations have been improved. In some instances the diagrams have the attached lettering and legends in German, but such words are translated in the index. The reappearance of a new edition of this work is eloquent testimony of the usefulness of this excellent compendium.

Précis de Sémiologie neuro-psychiatrique à l'Usage des Praticiens. A. ROUQUIER. Pp. 265. Paris: Gaston Doin et Cie. 1927. Price 32 francs.

An introduction to the clinical study of neurology and psychiatry, intended for students and practitioners of general medicine. The author undertakes his work under various chapters dealing with the symptomatology arising from disorders of various physiological and anatomical entities; thus he deals with the pyramidal tract, the cerebellum, the extrapyramidal motor system and the

the central nuclei, the sensory pathways, the progressive muscular diseases, the peripheral nerves, the syndromes of intracranial hypertension, speech disorders and syndromes of the organo-vegetative system. Following a general discussion of the symptomatology of each of these groups, the author proceeds to illustrate his argument by a short discussion of particular nerve disorders. Epidemic encephalitis is relegated to a chapter by itself. The choice of some of the illustrated examples is not always a happy one; thus Thomsen's disease, writer's cramp, torticollis and the choreas are dealt with in the chapters on disease of the basal ganglion, an assumption which may strike neurologists as premature and unwarranted.

The section dealing with psychiatry is divided up into the constitutional psychopathic states, the acute and the chronic mental disorders, the epilepsies and hysteria.

The text is illustrated by anatomical diagrams.

Le Peyotl : la Plante qui fait les Yeux émerveillés. Par A. ROUHIER. Pp. 372. Paris : Gaston Doin et Cie. 1927. Price 25 francs.

Amongst the most interesting of the lesser known drugs exercising their major effect upon the cerebrum must be ranked the sacred cactus of the Mexican Indians, the *Echinocactus Williamsii*, or peyotl. The drug is known to English medicine mainly under the name of mescal, and it is to Havelock Ellis and to Dixon, alone of British authors, that we owe most of our knowledge. Rouhier's monograph is by far the most complete treatise on the subject, and deals fully with the botanical, ethnological and pharmacological aspects. Amongst the Indians of the Southern States and of Mexico the plant is held in veneration, and concerning the origin of its cult there has arisen a wealth of folklore. Rouhier deals fully with this aspect, and describes the rituals and ceremonies with which the plant is gathered. The active principles of peyotl comprise numerous alkaloids, the most important of which are mescaline (a cerebral depressant, producing chromatopsia), anhalamine, anhalanidine, peyotline, anhalonine (soporific in small doses, producing tetanic spasms in larger amounts), and lophophorine (which antagonizes mescaline, increasing the irritability of the spinal reflex arc).

Peyotl is usually taken as a whole, either in the form of an alcoholic extract or combined with chloroform. The main action is that of a cerebral stimulant, but it has a selective effect upon the visuo-psychic centres; larger doses depress the cortex. Detailed accounts are given of its effect upon the human subject; with moderate doses, nothing untoward is experienced at first, beyond a mild sensation of gastric distension which later gives rise to nausea. A slight degree of vertigo next appears, which, far from being unpleasant, is accompanied by a sensation of exhilaration, or even euphoria. Visual acuity becomes exaggerated, so that objects stand out with especial clearness, and the field of vision increases, particularly for colours. Later, a sensation of lassitude is felt, and at this stage appear the characteristic visual hallucinations. At first, these are of a simple nature, and consist of coloured

vision, or the appearance of geometric figures, which arrange themselves into bizarre tapestry-like conformations. This kaleidoscopic effect is soon followed by the appearance of more complicated visions of faces, forms and landscapes. The images are ever changing and brilliantly coloured.

With larger doses, the complexity of the hallucinations increases still further, and combined visuo-auditory sensations are experienced, constituting the characteristic "audition colorée" of peyotl intoxication. Sounds heard in the room by the subject give rise to a constellation of visual images. Thus, each stroke of a pendulum may cause an "explosion of colour," or, as in a particular instance cited by Rouhier, the low notes of a piano produced a vision of violet, the high notes creating rose and white visions: a melody played over on the piano occasioned imposing visions of an architectural nature as "une salle de basilique ornée de statues." Long after the effect of the drug has dissipated, the memory of the hallucinations persists: apparently toleration to peyotl is not readily acquired.

Although employed by the Indians as a panacea, the status of peyotl in therapeutics is not established. Its use in cases of tabetic optic atrophy (Maloney) is not mentioned by Rouhier. The author believes that there must be a scope for its employment, and urges for more general usage. The excellent monograph is well printed and illustrated, and should be read in the original by all interested in the more obscure byways of pharmacology.

Disability in Reading and its Relation to Personality. By ELIZABETH HINCKS. Harvard Monograph Series. Pp. 92. Series I, Vol. II, No. 2. Harvard University Press. 1926. Price $1.

This monograph is the experimental consideration of eleven children of both sexes who were brought under psychological examination because of difficulty in acquiring the art of reading. In dealing with the work of other investigators the author points out how these cases first came under the eye of the ophthalmologist and the neurologist, as there appears to be at first sight defective perceptual development. The contribution of Gates to this interesting subject is given adequately and criticized.

In her researches the writer subjected her young patients to a whole range of psycho-physical tests. General intelligence was assessed, examination of visual field was made to rule out the possibility of homonymous hemianopia which frequently accompanies word-blindness. The whole range of visual perception was explored: Form-colour association; form-sound-colour; form-sound-meaning; form-meaning.

Handedness, which frequently shows disturbance or inversion, was examined. Eye movements were photographed. The details of the personal idiosyncrasies in each case are given, in addition to these psycho-physiological tests—each chapter presents a very satisfactory picture of the young subject. It seemed pretty evident from these cases that we are dealing with personality disturbances rather than with a primary defect of the mechanism of speech

and its various manifestations. It is apparent that when the monograph was written in 1922 the author had not as yet seen Head's scheme for assessing aphasic cases.

Individual Difference in the Intelligence of School Children. By MARY M. WENTWORTH. Harvard Education Studies, No. 7. Pp. 158. Harvard University Press. 1926. Price $2.

One thousand school children of the first grade of an American public school were taken for this investigation. Details of testing and the statistical lay-out of the subject cannot be given here, but the conclusions may be briefly stated :—

The intelligence quotient was found relatively stable throughout the group and there were no important sex differences. Racial factors were striking, i.e., North European stocks showing a median equal to the whole of the group. Differences of adaptability were evident and due to environmental divergences which affect the expression of intelligence rather than its quality. Retarded anatomical development was shown to correlate with retarded mentality. The investigation brought out the importance of a qualitative interpretation of the tests in conjunction with emotional and social sidelights. The whole personality of each child must be considered because expression of intelligence may suffer as result of factors emotional in origin. Thus a low I.Q. is not always of bad prognosis. One feels after all this testing that the disturbing element of environmental irritants causes inhibitions and retardations which are discoverable without testing of a laboratory kind, and which will alone explain many of the individual differences.

Faculty of Imagination : An Enquiry concerning the Existence of a General "Faculty" or Group Factor of Imagination. By A. L. HARGREAVES, M.A., Mus.B. Pp. 74. *Brit. Journ. Psych.* Monograph 10. Camb. Univ. Press. 1926. Price 7s. net.

As the author remarks in his introduction, little has been done by modern experimental methods to discover a group factor in Imagination. This we believe has been due to the generally accepted belief in the creative element in this process, and the diffidence naturally felt towards investigation of a process so elusive and so closely allied to artistic expression. Howbeit, modern methods have here been used with interesting results. Is the imagination—a unique mental element—a whole, or is it a composite of other factors already known ? Originality and fluency were taken by the investigator as marks of imagination, and tests were devised for the discovery of these as group factors, and, if so, if they correlate with one another. The tests are given in full, the scores of the subjects are tabulated and correlations given.

When fluency was considered on its quantitative side it correlated highly with intelligence tests and therefore it is assumed "to contain an appreciable element of the general factor 'g.'" It is compounded of speed and memory with other unknown conative elements.

The general conclusions drawn were that a general faculty of imagination does exist, and that fluency and originality go together to compose it and that each has a common element. The investigator is perturbed over the speed-factor which is obviously bound up with inhibitory processes too complicated to be pigeon-holed under hypothetical x and y factors. Here we are on the very threshold of emotion which is of the blood of imagination. If this is fully appreciated—and the author sees the prospect of the general factor disappearing with the fragmentation of it into minor factors—then the conative character of the imagination is made obvious—and thus it becomes very difficult to measure, at least by the usual tests.

Der sensitive Beziehungswahn. By ERNST KRETSCHMER. Second Edition corrected and enlarged. Pp. 199. Verlag Julius Springer. Berlin. 1927.

We have in English no convenient term to express the title of this work. The sensitive mania for relating things to oneself, the ease with which ideas of reference develop in certain sensitive types, is found in a larger group than that made familiar to us in the term paranoia. The work before us is an attempt to reconstruct the psychopathic character with special reference to paranoia.

In the older psychiatry this condition was merely discussed as a clinical entity, having as its nucleus systemized delusions based upon ideas of reference. Kraepelin, Kretschmer and Freud have helped us along the path of understanding this application as a complicated result of inter-psychical conflicts produced by disturbances of the sexual-emotional life. The problem is dealt with here with all Kretschmer's mastery in the marshalling of clinical material and acuteness in tracing processes through the labyrinth of the affective life.

Die psycho-kathartische Behandlung nervöser Störungen. By Dr. LUDWIG FRANK. Pp. 205. Verlag Geo.Thieme. Leipzig. 1927.

The cathartic investigation and treatment of the psycho-neuroses is discussed, and its distinguishing features are brought into relief as against methods of suggestion and re-education. The variety of visceral disturbances found in the thymopathic constitution is subjected to examination and related to their psychological correlates.

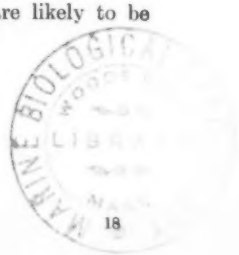
The Ego and the Id. By SIGMUND FREUD. The Psycho-Analytic Institute. Translated by Joan Riviere. The Hogarth Press. 1926.

We must thank the Psycho-Analytic Institute for bringing to English-reading people Freud's contribution to the psychology of the ego. The general lines of the theory were anticipated in the earlier works, particularly the group psychology, but in this volume the way in which the ego develops from its identification with persons closely associated with the child's personality in early life is carefully worked out. The interest of the theory lies in the fact that from this process of identification, and the creation of an ego-ideal, which becomes a system of reference for all later moral behaviour, we have Freud's contribution to the study of conscience. In the light of what is discovered from the Unconscious, the writer says we discover that man is much more moral and non-moral, *au fond*, than we ever believed him to be. Granting the empirical data upon which the theory is based, the book bristles with difficulties. What psychological warrant is there for supposing the existence of an Id at all? What is the relationship between the evolved conscience growing out of the ego-ideal and the objective moral judgments? Does the theory assume or conclude with a relationistic ethics? Perhaps Freud may round off his psychological work by enlightening us on these points.

Contributions to Psycho-Analysis. By SÀNDOV FERENCZI. The Psycho-Analytic Institute. Hogarth Press. 1927.

This considerable volume of essays and clinical fragments comes from one who, after Freud, has made the most original contributions to psycho-analytic theory. He has gone in many respects beyond Freud in the matter of technique, and fluttered the dovecots of the school by suggesting active interference in the process of analysis as against the passive method of the orthodox school. He suggests that in order to cut short the time involved one may impose inhibitions upon the patient in order that the pressure against resistance to disclosure of unconscious material will be too great to bear, and consequently inhibitions are broken down. The subject in this way cannot allow his conflict to escape through an act such as micturition, but is obliged to give up the psychological material involved in the mental conflict which resolves itself in the urinary act.

The rest of the book contains clinical fragments which are likely to be understood by the specialists only—or by the discerning ones!



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EDITOR.